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ON THE RATIO OF EXPANSION AT MAXIMUM EFFICIENCY.

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In all heat-engines the method of transformation of heat-energy into useful mechanical work is the following:

A certain mass of the working fluid is heated from a temperature which is usually not far from that of the atmosphere up to some higher temperature, T. This is accompanied by a definite increase of volume, or of pressure, or of both, and in the case of liquids by a change of physical state after passing a certain point which is variable, but definite for each pressure; this latter temperature is the boiling point and the change is that known as vaporization. Evaporation being complete, the mass is expanded until it has attained a certain larger volume, v_2, the magnitude of which is r times that of the initial volume, v_1, with which expansion began. We thus have the "*rate of expansion*," $r = \frac{v_2}{v_1}$.

When expansion is complete, the whole volume, v_2, of steam or gas at the pressure p_2 is rejected from the cylinder into a condenser or into the atmosphere, and the piston which it has impelled through the

total volume, v_2, returns to the starting point, resisted by the "*back*-pressure," p_3, of the condenser or of the atmosphere. During the latter operation all heat which has not been transformed into work is rejected, and an additional amount is expended, which is equivalent to the work done by the piston upon the fluid during its expulsion. This operation is also similar in result to the following: Instead of exhausting the working fluid as described, abstract heat from it at the maximum volume, v_2, until its pressure becomes equal to the back-pressure; then compress at the constant pressure p_3 until the fluid is restored to its original volume at the pressure p_3, which volume, in the case of the steam engine, may be neglected. In the case of the gas engine or hot air engine this volume is that of the working fluid at initial temperature and pressure.

This process is thus graphically represented: In Figure 1, the fluid, initially in the state measured by the pressure $a\ E$ or $a'\ E'$ and volume $O\ a$ or $O\ a'$, is heated, sometimes at constant volume, as $O\ a$, and sometimes with compression, as from $O\ a'$ to a higher temperature, the pressure and volume varying as shown by $E\ A$ or by $E'\ A$. Heated next at constant pressure or at constant temperature, the mass expands, doing work, to B or to B'. At this point, v_1, p_1, the supply of heat ceases and the fluid expands "adiabatically," transforming into mechanical energy all the heat demanded as equivalent to the work measured by the area $b\ B\ c\ C$, and drawing upon its own stock of heat to supply this demand. At the end of this stage the fluid has a lower temperature and a pressure and a volume, $c\ C$, $O\ c$ (p_2, v_2), determined by that temperature and the value of $r = \frac{v_2}{v_1}$, and which are indicated by the location of the point C.

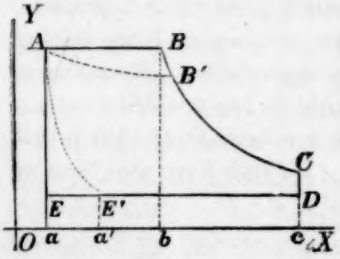


Fig. 1.

Rejecting heat at constant volume, v_2, pressure falls to D, p_3, and then rejection of heat continuing at constant pressure, p_3, the volume is reduced to that with which it started.

The *total* or *gross* work done is, in gas engines, measured by the area $A\ B\ C\ c\ a\ A$, in steam and vapor engines by this area increased by a very considerable amount—the measure of internal, of molecular, work which cannot appear on the indicator diagram.

The net work done is measured by the area included in the indicator diagram *A B C D E A*. This work is the equivalent of all heat transformed into mechanical work or energy. *The efficiency of the fluid* is the ratio of *net* work done to total heat received by the fluid, and is a maximum when the area *A B C D E* is a maximum, assuming the *rate of expansion* alone to vary. It is evident that this maximum is determined, therefore, by the conditions which make the area *b B c C* a maximum, which conditions are very simple in the hot air engine, and are easily expressed, while in the steam and in vapor engines they are very difficult of determination and expression in consequence of their extreme variability.

But the efficiency of the fluid is but one factor in the determination of the rate of expansion for maximum economy. The heat in the fluid is compelled to do its work, not simply through that fluid as a transmitting mechanism, but also through a machine which, as an apparatus intended to imprison and direct so subtle and elusive a form of energy as heat, is extremely imperfect, and which has the additional and very serious defect of being itself cumbersome and difficult to start and to keep in motion without considerable loss of power within itself.

The useful work of the machine is that which it transmits beyond its own boundaries to other mechanisms, and this is a maximum at that rate of expansion which gives energy to the machinery of transmission beyond the engine at least cost in heat expended. This *efficiency of the system* is therefore the product of two factors, the *efficiency of the fluid* and the *efficiency of the engine* consideredas a piece of mechanism.

(1) Taking first the purely ideal case in which the mechanism is assumed to be perfect and the rate of expansion the only variable element, we may by examining Figure 2 see at once what should be the value of that rate.

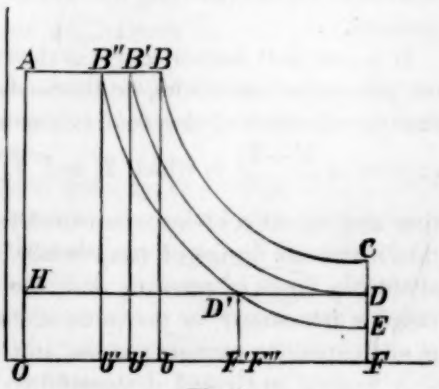


Fig. 2.

It is obvious that the rate of expansion simply determines how far the transformation of *stored*

heat-energy existing at B shall be continued by the development of work during the expansion of the working fluid. It is equally obvious that this expansion shall continue until the gain of work by further expansion is more than balanced by losses avoidable by termination of that process.

First: Where the only loss is due to a fixed back-pressure, $F D = p_3$, it is seen that, were expansion to cease at C, the work which would have been done had the expansion line $B C$ extended to the right, beyond C is lost, and that the counterwork of back pressure beyond that point is gained; but the former exceeds the latter and the net result is a loss by incomplete expansion. On the other hand, were the rate of expansion increased so that the expansion line becomes $B'' E$, the back-pressure line is reached at D'; beyond this point, we note a gain of work done usefully, which is measured by the area $D' E F F' D'$, while a loss accrues by back-pressure measured by $D' D F F' D'$. We thus again meet with a net loss which is represented by $D' D E D'$, and expansion has evidently been carried too far. Making the value of $r = \frac{v_2}{v_1}$ such that expansion reaches the back-pressure line at D and p_2 becomes equal to p_3, we meet with neither kind of loss, and it follows that expansion should in this ideal case be continued until the expansion line meets the back-pressure line.

This may be readily shown by other methods. It was shown, nearly two generations ago, by Sadi Carnot, that maximum efficiency of *fluid* is attained when expanding between the widest possible limits of temperature.

It is now well known, and it is shown by every elementary treatise on physics, or mechanics, or thermodynamics, and on heat-engines, that the efficiency of the *fluid* in any heat engines is measured by the expression $\frac{T_1 - T_2}{T_1}$ in which T_1 and T_2 are the temperatures of reception and rejection of heat measured from the "absolute" zero. But this maximum range of temperature corresponds to the maximum attainable range of pressure, and, the upper limit being fixed, this range is determined by the value of r and is a maximum when $p_2 = p_3$ and expansion continues to the back-pressure line.

A general analytical demonstration is obtained in the following manner: Given p_1, v_1, v_2, p_3 to find the value of *rate of expansion* r

to make the net work done a maximum. This work, *A B C D E*, Fig. 1, is measured by

$$W_n = p_1 v_1 + \int_{v_1}^{v_2} p\, dv - p_3 v_2; \tag{1}$$

it is a maximum when the variable part $\int_{v_1}^{v_2} p\, dv - p_3$ is a maximum.

The method of variation of p with variation of v is determined by various conditions which need not be discussed here and which do not affect our analysis. Let this relation be such that we may write, as experiment indicates that we may do with practically close approximation,

$$p_1 v_1^n = p_2 v_2^n.$$

Thus we have

$$W_n = p_1 v_1 + \int_{v_1}^{v_2} p\, dv - p_3 v_2;$$

$$= p_1 v_1 + \frac{p_1 v_1 - p_2 v_2}{n-1} - p_3 v_2; \tag{2}$$

or, where $n = 1$,

$$W_n = p_1 v_1 (1 + \log_e r) - p_3 v_2 \tag{3}$$

Determining the maximum for the first and usual case, we get

$$\frac{d W_n}{d r} = d\left(p_1 v_1 + \frac{p_1 v_1 - p_1 v_1 r^{1-n}}{n-1} - p_3 r v_1\right)\frac{1}{dr} = 0;$$

whence

$$r = \left(\frac{p_1 v_1}{p_3 v_1}\right)^{\frac{1}{n}} = \left(\frac{p_1 v_1}{p_2 v_1}\right)^{\frac{1}{n}} = \frac{v_2}{v_1} \tag{4}$$

Hence $p_3 = p_2$ and the rate of expansion for maximum efficiency is that which makes the terminal direct pressure equal to the pressure resisting the motion of the piston.

This analysis must be modified when the expansion line is an equilateral hyperbola, in which case we have $n = 1$ and $p_1 v_1 = p_2 v_2$. This case is often assumed in the theory of gas and air engines, as it is that of isothermal expansion; but it is probably rarely observed in actual practice, and perhaps never occurs in steam and vapor engines. In simple calculations of work, however, the assumption does not usually lead to serious error,* and, so expanding the working

*See a neat demonstration of this case by Professor Marks in the JOUR. FRANKLIN INSTITUTE, June, 1880.

fluid, the energy exerted by it up to the point of cut-off is equal to the lost work due to back pressure; the net work done is measured by the total area under the expansion line of the indicator diagram, and the efficiency is proportional to log. r.

Thus we have

$$W_1 = p_1 v_1 (1 + \log_e r) - p_3 r v_1$$

$$\frac{d W_1}{d r} = 0 = \frac{p_1 v_1}{r} - p_3 v_1$$

$$r = \frac{p_1}{p_3} = \frac{v_2}{v_1} = \frac{p_1}{p_2}; \qquad (5)$$

whence we again find $p_2 = p_3$.

(2) But in all real engines we have a resistance to the motion produced by the expanding fluid, which is composed of two parts, an actual back pressure on the piston $p_b = p_3$, as in the ideal case above, and a resistance due to friction of engine, including its pumps and attachments. It is evident that, as the latter, p_f, like the back pressure, p_b, is a constant source of lost work, we must terminate the expansion as soon as this source of loss produces a greater loss of power or of work than is gained by further expansion. In fact, given a certain value for the sum of these resistances, $R = p_b + p_f$, it is obvious that we may consider the whole as back pressure, if we choose, and that it is a matter of indifference, so far as the determination of the rate of expansion is concerned, what are their individual magnitudes.

To determine $R = p_b + p_f$, the sum of resistances due to back pressure, p_b, and to the frictional and other resistances—as of pumps, etc.—denoted by p_f, take an indicator card from the engine unloaded. Its mean pressure measures the friction, p_f, of the unloaded engine, and this, increased by a fraction of the pressure added by the load,* is the value of p_f. Or, still better, determine the indicated and the dynamometric power of the engine simultaneously; their difference is lost work, and the value of p_f corresponding to that work, is that required.

Hence, for actual engines, where no other cause of loss exists to any appreciable extent, as in some types of air engines, we may write

$$W_b = p_1 v_1 + \frac{p_1 v_1 - p_2 v_2}{n-1} - (p_3 + p_f) v_2 \qquad (5)$$

* Experiments made at the Novelty Works for the Navy Department, 1865–67, and others made later, do not exhibit this increase.

and by the process already outlined we obtain a maximum and deduce

$$p_2 = p_3 + p_f \qquad (6)$$

Hence: *Where the only variable loss is due to back pressure and to friction of the engine, the rate of expansion should be such as to cause expansion to the mean pressure line of the engine diagram taken without load;* the useful work is, as before, the gross work done during expansion, and, thus adjusted, the net useful work and the efficiency are nearly proportional to log. r.

These conclusions may be taken practically without qualification for all actual engines in which the working fluid is gaseous and subject to little direct loss of heat.

(3) For steam and other vapor engines still further and still greater modification is necessary, since in such engines the departure from the ideal conditions first assumed is not only greater than in gas and air engines, but is so great as, in most cases, to lead to radically different rates of expansion. Even in the gas engines, the action of the working fluid, as assumed above, is very greatly modified by such variations from the ideal conditions as are here referred to.

These engines—steam and vapor—are impelled by a fluid, which is a vastly better receiver and transmitter of heat than the permanent gases. Steam takes up and loses heat, in the processes of formation and of condensation, with extreme rapidity. The working fluid, in all steam engines, is readily condensible, and exchanges heat with the metallic surfaces of the working cylinder with the greatest freedom. It is usually more or less wet, and its humidity is subject to rapid and extreme variation in the course of the movement of the piston.

Explosive and other gas engines are impelled by a mixture of hot gaseous and vaporous products of combustion, of which the latter portion is, like the working fluid in the steam and other vapor engines, subject to rapid and considerable changes of thermal state. Enclosed, usually, in a chamber the sides of which are kept cool by a water-jacket, enormous quantities of heat are lost as expansion proceeds, and the efficiency of the machine is correspondingly diminished, and the economical rate of expansion is altered by the increased losses which accompany the higher rates. It is easily seen that, should these losses increase in a high ratio, with large rates of expansion, a point will be reached, and may be reached quickly, at which any greater expansion will result in a loss exceeding in amount the work gained by the extension of the expansion line. This point may be reached, and pro-

bably often is reached, long before attaining the limit set by the value of the resistances already studied. In such a case, we may call this limit that of the *virtual back pressure due to condensation*, and may designate it as p_c.

(4) In the steam engine a still more complicated set of phenomena is to be met with, and the result of their action is similar to that just described.

Suppose steam to enter the steam cylinder perfectly dry, and to expand *adiabatically.** As expansion progresses, after the closing of the steam valve by the expansion gear, the work done by the working fluid results in the transformation of so much heat into mechanical energy—which heat can now only be obtained by drawing upon the stock contained in the steam itself—that a part of the steam becomes liquefied.

This fact was shown by Rankine and by Clausius, by the study of the thermodynamics of the case; but it can easily and satisfactorily be shown by any student or engineer who will take the trouble to calculate the "total heats" of steam at the pressures found at the beginning and at the end of the expansion line. It will be found that the work done during the expansion is greater than the mechanical equivalent of this difference, and it follows that a part of it must have been done at the expense of the heat of evaporation of the expanding mass. This must be the case up to a limit at which the sensible heat of steam is just equal to the latent heat of the mass when indefinitely expanded at the absolute zero, and is about $\frac{1109550}{772} = 1437°$ ± absolute, a temperature only attained at the red heat.

Steam, therefore, condenses in the steam cylinder unless, by superheating or by the use of an efficient jacket, considerable heat is supplied it during expansion or before. This amount is, however, insignificant in comparison with direct losses of heat; it can probably never approach ten per cent. of the heat supplied, and is more likely, usually, to be a very much smaller figure, perhaps two or two and a half per cent. for average cases.

Initial condensation and later re-evaporation of steam in the steam engine, and initial condensation without subsequent re-evaporation, in gas engines, give rise to losses that are both absolutely and relatively very great wherever the range of temperature during expansion is very considerable, and especially with low back pressure.

* Without receiving or losing heat by exchange with surrounding surfaces.

The steam passing out of the exhaust ports to the condenser or into the atmosphere is moist and heavy with the water of condensation, and is a good conductor of heat as well as a very greedy absorbent. It sweeps out of the cylinder large quantities of heat abstracted from the inner surfaces of the cylinder, leaving those surfaces comparatively cold and wet with a chilling dew. The entering steam meets these cold metallic and liquid masses and is condensed in sufficient quantity to reheat them to the temperature of prime steam. As the piston moves forward it uncovers new surfaces, and condensation continues until, sometimes, a large fraction of the steam supplied lies in the cylinder or floats in the uncondensed steam as water and mist. Toward the end of expansion, and especially during exhaust, re-evaporation occurs at lower pressures and to a similarly serious extent. Thus heat is constantly transferred from the steam to the exhaust side, and, doing almost no work, is wasted, and the efficiency of the engine and the cost of fuel are greatly affected. The heat thus lost frequently amounts to 25 per cent. of the total supplied, and has been known not infrequently to amount to 50 per cent. In one case noted by the writer initial condensation was as high, *at least*, as 80 per cent.*

Since loss from this cause has been found to be so great, and to increase so rapidly with increased expansion, that it practically often sets an early limit to the economical increase of the rate of expansion, it is evident that we may determine a point such that, expansion being carried beyond it, the losses due this cause will exceed the gain of work done by the expanding fluid, precisely as in the cases already cited. Measuring the loss at such a point, we may determine the equivalent in foot-pounds of work, and thence deduce the magnitude of a new equivalent "*virtual* back pressure," $p_v = p_e$, which, if actually existing as such pressure, would similarly limit expansion.

* The extent of the loss from this cause is very seldom realized by engineers, and still less by unpractical writers on the theory of the steam engine. Even Rankine, the greatest of all known writers, seems to have failed to detect an initial condensation of 26 per cent, shown apparently by the value obtained for the index in his formula for the adiabatic expansion of steam $\left(p\ v^{\frac{1.0}{0}} = \text{constant} \right)$. He seems to check the discrepancy introduced into his analysis, amounting to a loss of about one-fourth of all heat supplied, by under-estimating the efficiency of the boilers, crediting them with but 0·54, where a low estimate, in the opinion of the writer, would be 0·65, and a fair figure would be 0·68 or 0·70 for the cases taken. The writer has never known the efficiency given in those estimates to be attained with boilers of such low value.

This value inserted in the formula representing the work of the steam would give a measure of the rate of expansion of maximum efficiency.

We should have, assuming no other losses:

$$W_e = p_1 v_1 + \frac{p_1 v_1 - p_2 v_2}{n-1} - p_e v_2 \qquad (7)$$

and should expand until $p_2 = p_e$, and make

$$r = \frac{v_2}{v_1} = \left(\frac{p_1}{p_e}\right)^{\frac{1}{n}}.$$

Thus, for all cases, whether of expansion of steam, of air, or of the products of combustion in explosive gas engines, we may determine for each case a certain "*virtual back pressure*," which we may call p_v, by which to identify a point beyond which continued expansion leads to a loss of heat, or of work, or of both combined, that is greater than the gain by work done* in that additional expansion, and may write generally:

$$W_v = p_1 v_1 + \frac{p_1 v_1 - p_1 v_1 r^{1-n}}{n-1} - p_1 v_1 r^{1-n} \qquad (8)$$

$$r = \left(\frac{p_1}{p_v}\right)^{\frac{1}{n}}.$$

Where, as in the case in which air expands isothermally, the expansion line is an equilateral hyperbola, it is seen that the loss by the virtual back pressure is always equal to the work done in the engine up to the point of cut-off; for $p_1 v_1 = p_v v_v$.

The net work done is always, for such expansion,

$$W_n = p_1 v_1 \log_e r = p_1 v_1 \log_e \frac{p_1}{p_v}.$$

In general, for the *net* work shown on the card as $p_2 = p_v = p_1 r^{-n}$; $p_v v_v = p_1 v_1 r^{1-n}$; $p_v r^n = p_1$, we get for net work:

$$W_n = \frac{n}{n-1} p_1 v_1 \frac{r^{n-1} - 1}{r^{n-1}} = \frac{n}{n-1} p_1 v_1 \left[1 - \left(\frac{p_1}{p_v}\right)^{\frac{1-n}{n}}\right]$$

$$= \frac{n}{n-1} p_1 v_1 \left(1 - \frac{1}{r^{n-1}}\right). \qquad (9)$$

* See "The Limitations of the Steam Engine," by Prof. Marks; JOURNAL FRANKLIN INSTITUTE, August, 1880. The use of the term "virtual back-pressure" is not logically correct, as the two methods of loss are quite different; but the writer has not yet found a more satisfactory term to take its place.

In the effort to determine the value of $p_v = p_e$ for this last method of loss of efficiency, we meet with great difficulties. The loss from initial condensation and later re-evaporation is the most serious of all those losses which in expansive engines are in any degree due to defects of the machine as a machine, and they are among those which are controllable to a considerable extent by the engineer. No two engines, however, ever exhibit them in the same degree, and modifying conditions are so numerous and so potent that the result of the most painstaking efforts to classify and to formulate them are likely to be exceedingly unsatisfactory.

This loss is proportionally greater as the range of temperature during expansion is greater; it is increased by slow speed of engine,* by reduction of the real back pressure, by increase in size of engine for a given amount of work done, by increase in conductivity of the surfaces of the working cylinder, and especially by wetness of steam. It is reduced by low rates of expansion, by increasing back pressures by reducing initial pressures, by increasing speed of engine and by special expedients, as steam-jacketing, superheating and the division of the expansion between two or more cylinders, as in "compound" or double-cylinder engines. Even increasing compression may reduce this loss and thus give a higher steam-line and an altered expansion-line.

The waste becomes the less, when the sides of cylinders only are jacketed, the smaller their diameter; it is lessened, when both heads and sides are jacketed, by increasing diameters, volumes being in both cases equal. With superheated steam, and where there is little initial condensation to be anticipated, the shape of cylinder is determined by the minimum ratio of volume to *internal* superfices, *i. e.*, $\frac{\text{diam.}}{\text{length}} = \frac{1}{2}$, except—as is often, if not usually, the case—when it is controlled by commercial considerations. The surfaces of the piston must evidently be included, since the principal losses—those due to initial condensation and to re-evaporation—occur upon those surfaces.

* With speeds so low that the range of temperature of cylinder surfaces is not restricted, the total weight of steam condensed is probably constant, and the loss becomes inversely as the speed of piston, or as the weight of steam passed through the engine. For fairly high and for very high speeds the writer takes this loss proportion to the reciprocal of the square root of the speed. See records of U. S. expansion experiments.

In general, we may say that the efficiency of an engine is some function of Δt, V, P and A; but the difference of temperature, Δt, is a function of pressures and time of exposure; the speed, V, determines time and exposure, and the area of surface exposed, A, is a function of volume, per unit of weight of steam, and of shape of cylinder. All of the conditions are so involved and interdependent that the simple approximate expressions to be presently given may be found preferable to any exact formula, even were it possible to devise them satisfactorily, and as these simple expressions yield, all things considered, very fair results, we may be fully justified in their use until extended and exact investigations shall yield better.

In gas engines the waste is decreased in those in which the working fluid meets only non-conducting surfaces, while it amounts as a minimum to 60 or 70 per cent. in some slow-running water-jacketed cylinders.

Again, we find some interesting compensations. The difference in back pressure between non-condensing and condensing engines is productive of such a wide difference in the range of temperatures worked through in usual cases, that the writer has been accustomed to consider the compensation so complete as to justify the assumption that the value of *this "virtual* back pressure" may be assumed to be independent of the magnitude of the actual back pressure, and to be determined solely by other conditions above noted. In steam-jacketed engines the efficiency of the steam-jacket is reduced by high speed, while the losses that it is designed to check are rendered less by the reduced effect of other causes of variation of the amount of initial condensation, and, while this compensation is by no means complete, the error introduced by the assumption that it is so may perhaps be neglected in presence of so many other and such complicated causes of irregularity of action. Our approximation must be anything but close at best. The exact expression would probably involve the Newton law of cooling and values of differences of temperatures, deduced from Rankine's formula: $\log. p = A - \frac{B}{T} - \frac{C}{T^2}$.

The best that the writer has been able to do in this direction, as yet, is to make simple and roughly approximate expressions for values of $p_t = p_v$, the proper terminal pressure, which, while widely departed from in many cases, may fairly represent average practice, and serve

as a guide to the designer and engineer until something better can be done, thus:

For the common unjacketed steam engine take the limit for p_v that determined by back pressure solely up to pressures of 6 or perhaps 7 atmospheres.

Then the terminal pressure should be, nearly, for non-condensing engines $p_t = p_v = p_b + p_f = 14{\cdot}7 + 3{\cdot}3 + 2 = 20$ lbs. per sq. inch (1·4 kilos. per sq. centimetre = 1·14 atmos.),* and we should expand to that pressure.

For condensing engines and for non-condensing engines under very high pressures, the limit is fixed by the extent of the losses of heat just described. For the common unjacketed engine at moderate speed the writer has been accustomed to assume for the rate of expansion giving maximum economy in the common single cylindered unjacketed engine, working at fair speed, $r_e < \frac{1}{2}\sqrt{P}$; for high-speed engines of best proportions and for compound engines, $r_e < \frac{3}{4}\sqrt{P}$ and $r_e < \sqrt{P}$ respectively. Where more variable conditions must be considered, he has written, for unjacketed cylinders or for ineffectively jacketed engines,

$$r_e = \frac{1}{p_v} = \frac{1}{p_e} = 0{\cdot}02\sqrt{VNP_1} = 0{\cdot}13\sqrt{V_m N P_m}, \text{ nearly};\dagger$$

$$p_t = p_v = p_e = \frac{50}{\sqrt{VNP_1}} = \frac{8}{\sqrt{V_m N P_m}}, \text{ nearly};$$

where S is the speed of piston, N the number of cylinders when the engine is "compound," P_1 and P_m are the initial pressures per square inch and per square centimetre, and p_t is the terminal pressure.

For well-jacketed engines we may take, roughly,

$$r_e = \frac{1}{p_v} = \frac{1}{p_e} = 0{\cdot}5\sqrt{NP_1} = 1{\cdot}75\sqrt{NP_m}, \text{ nearly.}$$

$$p_t = p_v = p_e = \frac{2}{\sqrt{NP_1}} = \frac{0{\cdot}6}{\sqrt{NP_m}}, \text{ nearly.}$$

* With large ports and dry exhaust steam this figure should be reduced 10 per cent.

† Emery has proposed, as fair values, $r_2 = \frac{P+37}{22}$, where P is the *gauge* pressure, and considers the values thus obtained as large for ordinary single cylinder engines, and small for the best compound engines.

In determining the values of the index n in the assumed expression pv^n = constant, for the equation of the expansion line, new difficulties arise. This index is itself variable in each case as expansion progresses, and no two cases give the same mean value. Rankine takes $n = \frac{10}{9}$ for expansion in non-conducting cylinders, assuming that in those engines on which he experimented the conditions were practically such as to give this value. The writer has no doubt that the steam supplied them was practically dry, but Zeuner has shown that the value of n is pretty nearly

$$n = 1{\cdot}035 + \frac{x}{10}$$

where x measures the proportion of steam present or the "dryness fraction." For $x = 1$, $n = 1{\cdot}135$, as tabulated, and for $n = 1{\cdot}111$, as taken by Rankine, we have

$$x = 10\ (1{\cdot}111 - 1{\cdot}035) = 0{\cdot}76,$$

showing that initial condensation must have produced 24 per cent. water, a fact which introduces an error in his estimates of heat supplied to the engine from the boiler.

In none of the values above given is the fact exhibited that the effect of the phenomenon here studied at some length is to cause a rapid fall of the expansion line at the start and a considerable rise at the end, thus causing the line to depart from the curve represented by $pv^n = C$ to an extent that cannot be definitely stated. The value of the index is rendered by this cause, also, not only very variable for different cases, but it is probably usually varied constantly along the expansion line in each case by these new variable conditions. So great are these departures from any laws yet expressed by formulas that we may be justified often in taking advantage of the fact that the curve as often approaches the equilateral hyperbola as any other regular curve.

Where steam-jacketing is so efficient as to prevent condensation during expansion, and where, assuming it possible, superheating can be made so effective as to prevent initial condensation, the transfer of heat from steam to exhaust without transformation into work, in the manner here considered, would be greatly reduced, and perhaps so far as to make the limit $p_v = p_e + p_b$, as in non-condensing engines with low steam.

The compound engine, with receiver, offers peculiar opportunities to secure these conditions by superheating between the two cylinders, as has been done by Corliss, Leavitt and others.

The last column of the large table exhibits this case, assuming $p_r = p_c = p_b + p_f = 7\frac{1}{2}$ lbs. The value of r is increased for a given value of p_b, often to a considerable extent in actual engines, by re-evaporation.

The tabulated values of r_c may be taken as maxima for low pressures and minima for high steam, and in the latter case considerable departures from them in the direction of larger values have often produced but little difference of efficiency.

The following are values of n for various cases commonly found in real work, or taken in theoretical discussions:

VALUES of n IN pv^n = CONSTANT.

Air, isothermal expansion,	1·0
" adiabatic "	1·4
" wet and adiabatic,	1·2
Gases generally, isothermal,	1·0
" " adiabatic,	1·4
" in explosive gas engines,	1·6
Steam, dry and saturated,	1·046
" adiabatic,	1·135
Steam, 0·76; water, 0·24,	1·111
" superheated,	1·333
Steam and water generally,	$n = 1{\cdot}035 + \frac{x}{10}$

The absolute values of the weights of steam used in engines under the conditions above considered cannot be predicted with any greater accuracy than the proper rates of expansion. The expenditure of heat in this method of waste increases in some undetermined ratio with the increase of the rate of expansion, and the writer has usually anticipated a loss at least proportional to the square root of that rate, and would add a percentage equal usually to at least $h_c = 0{\cdot}1 \sqrt{r_c}$, and often to $h_c = {\cdot}25 \sqrt{r_c}$, to the amount calculated ordinarily by Rankine's methods, and would expect the weight of steam used to reach $W = \frac{200}{\sqrt{P_1}}$; $W = \frac{24}{\sqrt{P_m}}$; nearly, in general practice and with good engines

Probable Terminal Pressures and Rates of Expansion at Maximum Efficiency.

Initial Pressures. *Absolute.*		Speed of Piston.		Single Cylinders. Non-condensing. Unjacketed. $p_t = p_v$		r_e	Jacketed. $p_t = p_v$		r_e	Condensing. Unjacketed. $p_t = p_v = p_c$		r_e	Jacketed. $p_t = p_v = p_c$		r_e	Compound ($N=2$) Condensing. Sides jacketed. $p_t = p_v = p_c$		r_e	Heads and sides jacketed. $p_t = p_v = p_c$		r_e	Heads and sides jacketed with efficient superheating. $p_t = p_v = p_b + p_f$		r_e
P_i	P_m	V	V_m	Lbs. on sq.in.	Kilos on sq.cm.		Lbs. on sq.in.	Kilos on sq.cm.		Lbs. on sq.in.	Kilos on sq.cm.		Lbs. on sq.in.	Kilos on sq.cm.		Lbs. on sq.in.	Kilos on sq.cm.		Lbs. on sq.in.	Kilos on sq.cm.		Lbs. on sq.in.	Kilos on sq.cm.	
40	2·8	400	122	20	1·4	2·0	20	1·4	2·0	16	1·1	2·5	13	·9	3·0	9	·6	4·5	7	·5	6	7½	·5	5
		625	185	20	1·4	2·0	20	1·4	2·0	13	·9	3·0	13	·9	3·0	9	·6	4·5	7	·5	6	7½	·5	5
60	4·2	400	122	20	1·4	3·0	20	1·4	3·0	20	1·4	3·0	15	1·1	4·0	11	·8	5·5	8	·6	7·5	7½	·5	8
		625	185	20	1·4	3·0	20	1·4	3·0	15	1·1	4·0	15	1·1	4·0	11	·8	5·5	8	·6	7·5	7½	·5	8
80	5·6	400	122	23	1·6	3·5	20	1·4	4·0	23	1·6	3·5	18	1·3	4·5	13	·9	6·5	9	·6	9	7½	·5	11
		625	185	20	1·4	4·0	20	1·4	4·0	18	1·3	4·5	18	1·3	4·5	13	·9	6·5	9	·6	9	7½	·5	11
100	7·0	400	122	25	1·8	4·0	20	1·4	5·0	25	1·8	4	20	1·4	5·0	14	1·1	7·0	10	·7	10	7½	·5	13
		625	185	20	1·4	5·0	20	1·4	5·0	20	1·4	5	20	1·4	5·0	14	1·1	7·0	10	·7	10	7½	·5	13
120	8·4	400	122	27	1·9	4·5	22	1·5	5·5	27	1·9	4·5	22	1·5	5·5	16	1·1	7·5	11	·8	10·5	7½	·5	17
		625	185	22	1·5	5·5	22	1·5	5·5	22	1·5	5·5	22	1·8	5·5	16	1·1	7·5	11	·8	10·5	7½	·5	17
150	10·5	400	122	30	2·1	5·0	25	1·8	6	30	2·1	5·0	25	1·8	6·0	18	1·3	8·5	12·5	·9	12	7½	·5	20
		625	185	25	1·8	6·0	25	1·8	6	25	1·8	6·0	25	1·1	6·0	18	1·3	8·5	12·5	·9	12	7½	·5	20
200	14·1	400	122	36	2·6	5·5	29	2·1	7	36	2·5	5·5	29	2·1	7·0	20	1·4	10·0	14	1·0	14	7½	·5	27
		625	185	29	2·1	7·0	29	2·1	7	29	2·1	7·0	29	2·1	7·0	20	1·4	10·0	14	1·0	14	7½	·5	27

$p_t = p_v$ is taken as equal to p_c except where $p_v = p_b + p_f$ exceeds p_c, when this greater value is adopted; *e.g.*, in non-condensing engines with low steam, and in highly superheated steam engines.

Deduct 14·7 lbs. per sq. in. = 1 kg. per sq. cm. to obtain gauge pressures. Hyperbolic expansion is assumed.

In the general expression for loss by initial condensation, $h_c = a \sqrt{r_c}$, the writer has used the following values for the coefficient a:

Unjacketed cylinders, . . .	$\begin{cases} 1600 \div Vd \\ 1200 \div V_m d_m \end{cases}$
Cylinders with sides jacketed, .	0·10
Cylinders with sides and heads jacketed, .	0·07

in which d and d_m are diameters of cylinders in inches and centimetres and V and V_m are velocities of piston in feet and metres.

Similarly rough statements of probable weight of steam per horse-power and per hour for a wider range of *average* good conditions, as used by the writer, have been (minima)

$$W = \frac{40}{\log.\ P_1}; \quad W_m = \frac{7{\cdot}7}{\log.\ P_m}, \text{ for fast or jacketed engines;}$$

$$W = \frac{100}{\log.(P_1 V)}; \quad W_m = \frac{20}{\log.(P_m V_m)}, \text{ for unjacketed cylinders.}$$

Where the ratios of expansion have been made those of maximum efficiency, the closest approximation has been attained by taking

$$W = \frac{15}{\log.\ r_c}(1+{\cdot}1\sqrt{r_c}); \quad W_m = \frac{7{\cdot}}{\log.\ r_c}(1+{\cdot}1\sqrt{r_c}),$$

as the expenditure will in such cases approximate most nearly to a direct ratio with the net energy obtained per diagram. These values are adopted in the following table. It is evident that the higher the value of r_c, the better the type of engine, and that we are here given a good gauge by which to make comparisons of the efficiency of different kinds of engines.

These values accord moderately well with the observation and experience of the writer where engines of good design have been compared, and may possibly prove useful to others in designing or in drawing up specifications. Like the values of p_v or of r, they can only be taken as probable means, and adopted provisionally, until better and more accurate values have been determined for a wider range of conditions.

Thus, we have the following probable values of weight of steam demanded where the ratio of expansion is correctly adjusted:

Probable Minimum Weights of Steam per Hour per Horse-power.

r_e	W Pounds.	W_m Kilos.	r_e	W Pounds.	W_m Kilos.	r_e	W Pounds.	W_m Kilos.
3	32	15	8	20	9	13	19	8
4	27	12	9	19	9	14	16	7
5	25	11	10	19	9	16	16	7
6	22	11	11	18	9	20	15	7
7	20	9	12	17	8	25	15	7

Taking the probable minimum expenditure of coal per hour and per horse-power at *one-ninth* the weight of steam demanded, we get

$$W' = \frac{1{\cdot}7}{\log.\ r_e}\,(1+0{\cdot}1\sqrt{r_e}),\quad W'_m = \frac{{\cdot}8}{\log.\ r_e}\,(1+0{\cdot}1\sqrt{r_e}).$$

and thus, assuming, as before, the best probable conditions and the ratio of expansion giving a minimum cost of steam, we obtain the following:

Probable Minimum Weights of Coal per Horse-power per Hour.

r_e	W' Pounds.	W'_m Kilos.	r_e	W' Pounds.	W'_m Kilos.	r_e	W' Pounds.	W'_m Kilos.
3	3·5	1·6	8	2·2	1·0	13	1·8	0·9
4	3·0	1·4	9	2·1	1·0	14	1·8	0·8
5	2·8	1·3	10	2·1	1·0	16	1·8	0·8
6	2·3	1·1	11	2·0	0·9	20	1·7	0·8
7	2·2	1·0	12	1·9	0·9	25	1·7	0·8

For cases in which the boiler gives an evaporation of ten pounds of water per pound of coal we may get ten per cent. better figures.*

* A private letter, lying on the table of the writer, giving results corresponding with the case assumed as giving $r_e = 20$, states the coal consumption at 1·5 pounds. This is obtained by one of the oldest and most distinguished engineers in the United States. The boiler has about this maximum efficiency.

So far as the experience of the writer and comparisons made by him with data given by the best experiments have extended, these figures have proven so far accordant that he does not hesitate to use them in estimating probable results. Adding, say, 20 per cent. will give figures on which to base a guarantee in making up contracts, for skillfully designed engines.

The introduction of this element practically completes the theory of the steam engine. Every practicing engineer will look with interest for experimentally derived data and exact expressions that may replace approximate formulas which as here provisionally used are purely empirical and have no scientific value.

How far the high efficiencies here seen to be probably attainable are worth paying for is a commercial question of great importance, but is quite distinct from that here considered.

REFERENCES.—The quantities and the empirical formulas and rules given by the writer as deduced from experience and observation may be compared with the following, which comprise nearly all that he has been able to find bearing upon the subject with any degree of definiteness: D. K. Clarke, "Manual for Mechanical Engineers," pp. 888, 890; "Northcott on the Steam Engine," pp. 157, 158; Isherwood's "Engineering Researches"; "Cotterill on the Steam Engine," chap. xi, especially pp. 294 to 296; R. H. Buel's "Addenda„ to "Du Bois' Weisbach," vol. ii, § 512; Rankine's "Papers"; Rankine's "Steam Engine," § 282, 289; "Porter on the Richards Indicator," London, 1874, sect. iii.

New Actinic Phenomenon.—M. Phipson prepares a zinc white by precipitating a sulphate of zinc by means of a more or less complete solution of barium sulphide. The precipitate is placed under a hydraulic press and then heated to redness in a furnace, care being taken to prevent too great oxidation. When the experiment is properly conducted and the product is exposed to sunlight the snowy white gives place gradually to a brownish tint, which becomes of a slate color in about twenty minutes. If placed again in the darkness the dark shade is gradually lost, and in the course of five or six hours it becomes as white as snow. The experiment may be repeated with the same specimen as often as may be wished.—*Les Mondes.* C.

THE WOOTTEN LOCOMOTIVE ENGINE.

By J. Snowden Bell.

A review of the recent practice in and present status of American locomotive engineering, will evince the fact that, in their efforts to answer the requirements of increased tractive power and higher speed, constructors have been, as a rule, confined to such enlargement of the capacity of the engine as is resultant upon the increase of its dimensions, without material variation, either in principle or details, from patterns which have become standard for different classes of service. This is particularly the case respecting boilers, the ordinary type, with plain furnace and fire tubes extending from the fire box to the smoke box, having entirely displaced the limited number of special constructions differing materially therefrom, which were devised and made the subject of more or less extended practical tests, at and soon after the general introduction of coal as fuel. The most prominent of these were the Boardman boiler (central flue and hanging fire tubes, 1849), the Dimpfel (water tube, 1850), the Milholland (double series of fire tubes, with intermediate combustion chamber, 1852), and the Phleger (lower and upper water bridges and combustion chamber, 1856), each of which was abandoned, after having been brought into use to an extent sufficient to indicate, in actual service, a lack of practical value. The Norris Locomotive Works, of Philadelphia, built a number of coal-burning engines with the Phleger boiler, and also essayed the introduction of a boiler patented by Wm. G. Norris, in 1857, the latter being analogous to that of Milholland, but their efforts were not crowned with success, and thereafter the ordinary boiler, with an increased proportion of fire surface, became the universal practice.

The necessity of enlarging the grate and fire box area, in boilers for coal-burning engines, met with early recognition, and the late Ross Winans and James Milholland, who were the earliest constructors upon a large scale, first made a compliance with this requisite a special feature in their engines. Each using an overhung fire box, Winans lengthened and Milholland widened it, the increased grate area of the latter being obtained by laterally extending the fire box below the frames and beyond the driving wheels. This construction was not

adaptable to engines for passenger service, having driving wheels of comparatively large diameter on an axle located below or behind the fire box, and the long furnace of Winans, being the only one suited to such conditions, was adopted, under different modifications, and is at the present time the standard for the ordinary anthracite coal-burning passenger engine. The efficiency of the Winans furnace was and is restricted by the limitation placed upon its lateral extension by reason of its position between the wheels, such increase of width as is obtainable by the employment of thin or "slab" frames, or even by the elevation of the furnace above the frames, being comparatively inconsiderable.

Mr. J. E. Wootten, General Manager of the Philadelphia and Reading Railroad, has designed and constructed a locomotive boiler, which is the most recent and most notable departure from the standard American practice. The object sought, and, as evidenced by the performance of the engines, successfully accomplished, was to enable any desired amount of grate area to be employed, in a boiler adaptable to all classes of locomotive engines, and to thereby attain the resultant advantages, not only of perfecting the combustion of anthracite as ordinarily prepared, but also of rendering practicable and economical the consumption of a fuel which it has not been hitherto possible to burn in locomotive furnaces, namely, fine anthracite or "buckwheat" coal (previously a waste product of the Pennsylvania anthracite regions) and lignite, or fossil wood. The distinguishing characteristic of the Wootten locomotive is, in brief, a fire box which is extended laterally over the driving wheels, without materially elevating the waist or body of the boiler. The width of a fire box, upon this plan, may be as great as desired, within the limits fixed by the distance between the tracks, that is to say, as wide as any car which will pass over the road, and the undue elevation of the boiler is avoided by the use of a fire bridge interposed between the furnace and an adjacent combustion chamber within the waist of the boiler, the height of the bridge being equivalent to the depth of the front water leg in an ordinary anthracite coal-burning boiler.

This fire box was designed specially for the utilization, as fuel, of the waste produced in the mining and preparation of anthracite coal. This refuse material amounts to from 20 to 25 per cent. of the output of the mines of Pennsylvania, which for the past year was, in round

numbers, 23,000,000 tons. There is usually mixed with it from 18 to 20 per cent. of slate and other impurities, the elimination of these being effected by the jigging process, which thoroughly separates the coal by agitation in water, the denser slate falling to the bottom, whilst the lighter carbon passes off at the surface. For some time, the unseparated waste, as delivered from the smallest mesh screens, was used in these engines, but the large percentage of contained incombustible matter rendered it necessary to so frequently clean the fire, that it was found more desirable to separate such matter before supplying the fuel to the tender than to perform a corresponding operation in the furnace while in service. It will be obvious that the fine particles thus made available as fuel can only be consumed in a furnace, the draught of which is so gentle as not to lift them from the grate, and it is in this particular that the enlarged grate of the Wootten engine, by the diffusion of the draught over a very large area, serves the purpose of maintaining comparative quietude of the fuel, even under the intense action of the exhaust blast.

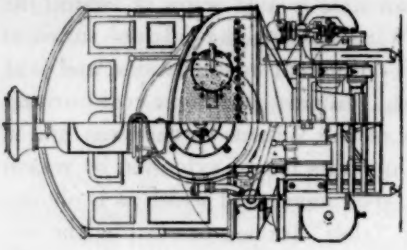


Fig. 2.

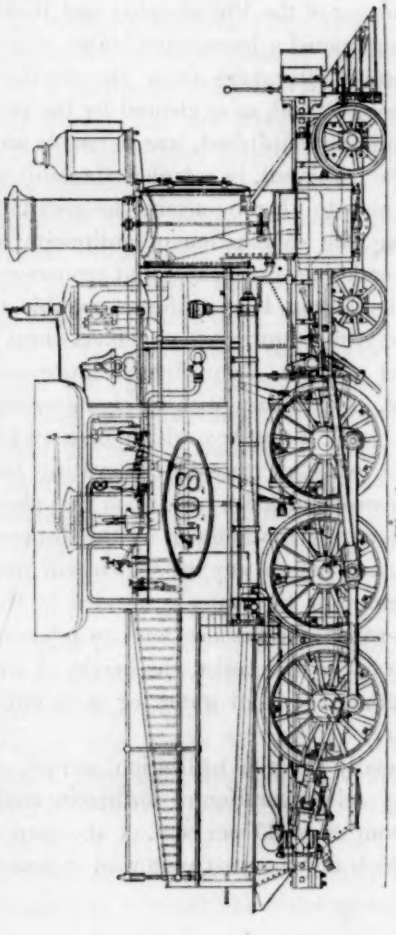


Fig. 1.

The first engine of this construction, No. 408 of the Phil-

adelphia and Reading Railroad, illustrated in Figs. 1 and 2, was built at the Reading shops of that company, and put in service about four years since. It is of the ten-wheeled class, having six coupled driving wheels and a four-wheeled leading truck, is designed for fast freight service, and is of the following general dimensions:

Cylinders,	18 x 24 in.
Diameter of driving wheels,	54 in.
Diameter of truck wheels,	30 in.
Wheel base,	20 ft. 5 in.
Diameter of boiler at smoke box,	45½ in.
Diameter of boiler at fire box,	54 in.
Number of tubes,	160
Length of tubes,	10 ft. 2 in.
Diameter of tubes (outside),	2 in.
Length of fire box (inside),	8 ft. 6 in.
Width of fire box (inside),	7 ft. 6½ in.
Combustion chamber,	31 in. long
Grate area,	64 sq. ft.
Heating surface of tubes,	850 sq. ft.
Heating surface of fire box,	106 sq. ft.
Heating surface of combustion chamber,	26 sq. ft.
Total heating surface,	982 sq. ft.
Diameter of smoke stack,	20½ in.
Exhaust nozzle, variable from	4 to 5 in. diam.
Weight on driving wheels,	67,900 lbs.
Total weight of engine,	86,150 lbs.

The performance of this engine was such as to justify the construction of others having furnaces of the same plan, and at the present time there are about 75 in use upon the Philadelphia and Reading and other railroads having access to the anthracite region.

An engine of similar design and dimensions (No. 412) was exhibited at the Paris Exposition of 1878, and was thereafter made the subject of experiments upon Chemin de Fer du Nord, of France, using as fuel anthracite coal and *briquets* composed of pulverized bituminous coal and coal tar. It was also tested upon the Alta Italia Railway, in Italy, by order of the government of that country, using anthracite and the native lignites of various localities. The report of its performance on the latter road, made by the government engineers Fadda, Codazza and Senesi, and dated July 14th, 1879, which has

not heretofore been published, evinces that upon a careful and thorough examination and practical test of its construction and capabilities, these engineers found much in the American machine to approve and nothing to condemn. The developments made in their experiments induced the Northern Pacific Railroad Company to investigate the practicability of burning lignite, which exists in considerable quantities within easy reach of their line, and, accordingly, some ten or fifteen tons of this fuel were forwarded to Philadelphia in December last, for trial in one of the consolidation engines in use on the Reading Railroad. The result was so satisfactory that several engines have been ordered by the Northern Pacific Company, and are now under construction at the Baldwin Locomotive Works. These engines will have 18 x 24-inch cylinders, and a grate area of 81 square feet.

The following summary of the deductions expressed by the engineers in charge of the Alta Italia tests, will indicate the extent and accuracy of their observations, as well as illustrate the capabilities of the furnace with lignite as fuel.

The report states that, with the lignite of Monte Murlo (Tuscany), the average of evaporation of two succeeding trips was 4·20 kilogrammes of water for each kilogramme of fuel. This lignite gave a fine and even fire, without a very long flame, scarcely a perceptible odor of sulphur, no sparks from the stack, and no residue of combustion in the smoke box or tube, "as is ordinarily the case in our locomotives." The latter feature, being the same with all the qualities of fuel employed, is attributed by the engineers to the special form of the furnace, regarding which they note that its very large grate surface allows the air to pass through the grate at a moderate velocity, and without drawing into the tubes with the hot gases, small pieces of fuel or other residue of combustion. Referring to the mode of firing, which is stated to be "regular and demands no excessive fatigue for the fireman," it is noted that "a certain practice only is necessary to throw the fuel to a distance of more than two metres, and to keep it equally distributed over the surface of the grate."

Three experiments with anthracite indicated a ratio of evaporation of 8·36, and this fuel is commended as possessing the very highest evaporative effect. A shallow furnace is held to be indispensable, and it is considered that the Italian engines could not be suited to its use without such modifications as would make them almost identical with the Wootten engine. In this connection, it is noted that

upon one of the trials the fire of *briquets* (artificial fuel) having given out, the steam pressure fell to 45 lbs., but that, with a delay of only ten minutes, the fire was started anew, and a sufficient pressure attained to continue the trip.

Two trips were made using the lignite of Cludunco (near Treviso). This lignite was almost all dust, but burned very well, with no escape of sparks or traces in the smoke box, giving an average evaporation of 8·66 kilog. of water per kilog. of fuel. The special objection to it is stated to be the large amount of sulphur which it contains. A third trial with the Cludunco lignite, using the injector instead of the pump and heater, indicated a ratio of evaporation of 8·82.

Cardiff coal dust, used in one trip, burned perfectly, without sparks or deposit in the smoke box, and with a ratio of evaporation of 8·90.

The lignite of San Giovanni (Tuscany) is described as having the external appearance of wood, and is very light and therefore easily carried off with the escaping gases. Nevertheless, it burned quietly, without sparks and with good evaporative power. The lignite of Valdagno burned with a beautiful flame, and gave an excellent result. It is remarked that this, being found in alluvial soil, is mixed with much small gravel, and also contains a certain quantity of pyrites.

As a result of the tests, the engineers express the opinion that with arrangements analogous to the Wootten furnace the Italian fuels can be conveniently consumed in their engines. They say, further: "In the secondary order of fuels, Italy is sufficiently rich, and *it would, therefore, be very desirable that this product should receive careful study, to enable us to emancipate ourselves, in part at least, from dependence upon foreign countries for fuel.*" They commend the excellent qualities of American anthracite, and indicate that the advisability of its adoption depends only upon the determination of the question of its cost and that of the necessary modification of their fire boxes.

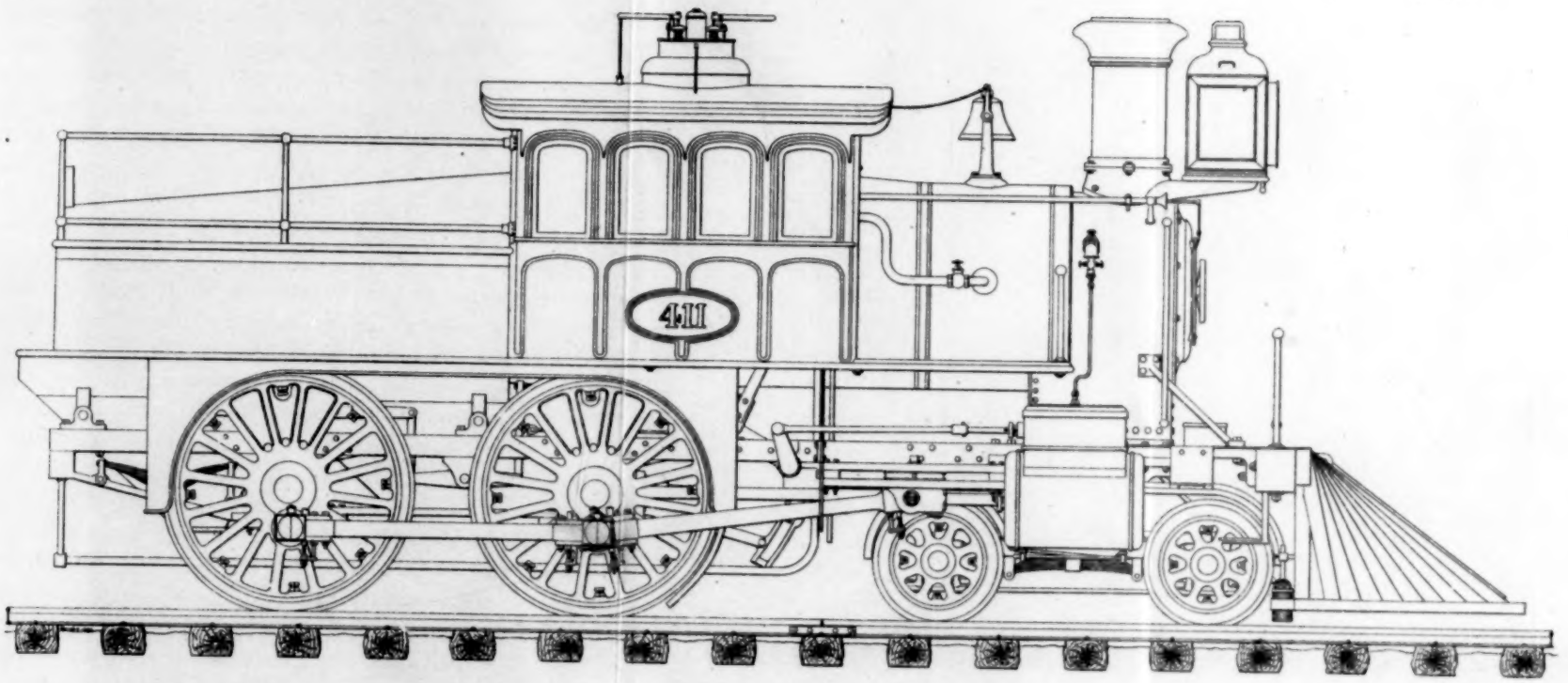
A full description of the engine is given, with notes of approval of sundry points which were novel to the Italian practice, and it is stated that, notwithstanding the form of the engine, its centre of gravity was not unduly high; that it rode with stability, and worked with ease through sharp curves, its truck obviating shocks or oscil-

lations, even at velocities of from 40 to 50 kilometres. The report concludes with the statement that, as compared with the Italian engines of the fourth category, the locomotive under consideration is superior in respect of the smaller resistance of its mechanism.

The very free steaming qualities of these engines led to the application of boilers of like design to locomotives intended for passenger service at high velocities, and, although the construction necessarily involves an unusually high centre of gravity in the engine, yet it has been developed by experience, not only that this feature is wholly unobjectionable, but also that it contributes in a marked degree to the steadiness of the engine when running at high speeds upon either curves or tangents. The passenger engines employed in the fast train service have not, as yet, used the waste of the mine as fuel, although in ordinary passenger service its use has been attended with entire success.

An example of a fast express engine, of the largest and most powerful class yet constructed, is illustrated in Figs. 3, 4 and 5, being an elevation and sections of engine No. 411 of the Philadelphia and Reading Railroad, one of a series running fast passenger trains between Philadelphia and Bound Brook. These engines, which were built at the company's Reading shops, exceed in weight, heating surface of fire box, and boiler and cylinder capacity, any passenger engines ever built in the United States. Two of these (Nos. 411 and 506) have cylinders 21 in. x 22 in., driving wheels 5 ft. 8 in. diameter, and weigh 98,200 lbs., of which 64,250 lbs. are upon the driving wheels. Twelve other passenger engines, having boilers upon the same plan, are now in service, in one of which, on the Camden and Atlantic Railroad, bituminous coal is used for fuel with very satisfactory results. In this engine the forward part of the grate has been paved with fire brick, covering about 16 square feet, thus increasing the volume of space available as a combustion chamber relatively to the grate area, and preventing almost entirely the issue of smoke from the stack.

The construction of the boiler, as shown in Figs. 4 and 5, needs but little explanation. The fire box, as in all engines on this plan, is placed entirely above the driving wheels, its exterior width being 8 feet 8 inches, and its length 10 feet 5 inches. The grate area is 76 square feet, and the grate is composed of water tubes and bars, arranged alternately and extending on a slight downward incline from



J. Snowden Bell, del.

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WOOTTEN'S FAST EXPRESS ENGINE.

D. A. PARTRIDGE, PHOTO-LITH. 624 ARCH ST., PHILA.

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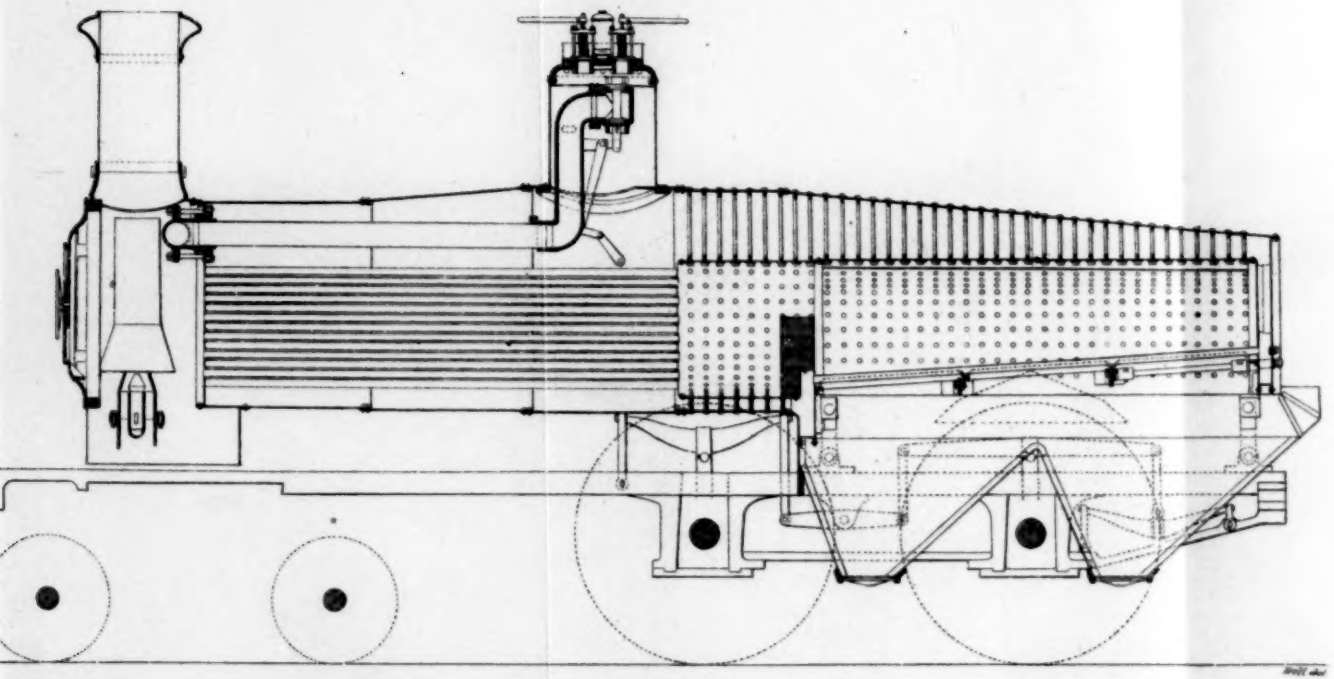

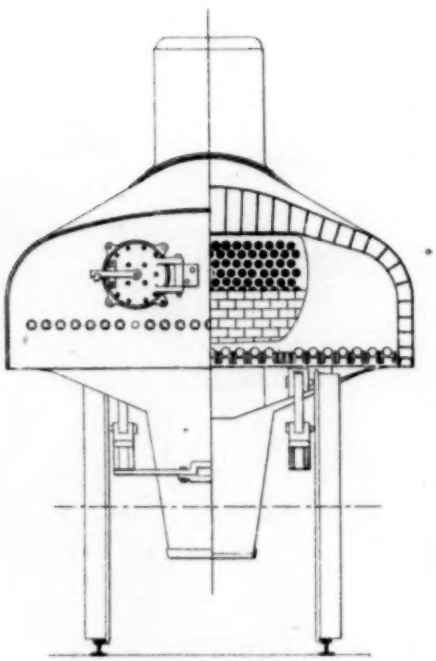

WOOTTEN'S FAST EXPRESS ENGINE.

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the back of the furnace, in which there are two round firing doors 17 inches in diameter, and placed 38 inches between centres. At the front end of the fire box there is a fire brick bridge, the top of which is 18 inches above the grate. A combustion chamber 27 inches long is formed in the waist of the boiler between the flue sheet and the bridge wall, and is connected by 184 2-inch tubes with the smoke box, which is 54 inches in diameter and 30 inches long from flue head to front. The waist of the boiler is 53 inches in diameter at the smoke box end and 59 inches at its junction with the fire box. There is a single dome 28x28 inches located in advance of the combustion chamber. No crown bars are employed, instead of which the crown sheet is stayed by 279 $\frac{7}{8}$ stay bolts, screwed into the outer and inner casings of the fire box and combustion chamber, their outer ends being riveted over and their inner ends additionally secured by nuts. The use of stay bolts in lieu of crown stays, although by no means a new idea (see T. R. Crampton's French patent, March 24, 1849, and Ross Winan's U. S. patent, May 9, 1854) has latterly been extensively applied, both in this country and in Europe, and so far as the writer's observation and information extend, the system has proven itself to be satisfactory and efficient. A plain open stack, 48 inches high and 21 inches in diameter, the top of which is 14 feet above rail, is used, and there is a register in the smoke box door by which the draught may be diminished by the engineman as required. The exhaust, which has a single nozzle, is variable, by means of an internal cone in the exhaust pipe, which can be raised and lowered, so as to vary the exit opening between limits corresponding to the areas of $3\frac{3}{4}$ inches minimum and $5\frac{3}{4}$ inches maximum diameters respectively.

The cylinders are secured to each other and to the frames on the "half saddle" plan, now universally adopted in the United States, and, owing to the peculiar form of the furnace, a novel spring arrangement and suspension of the rear end of the boiler has been adopted. The smoke box is bolted firmly to flanges on the saddle portions of the cylinder castings, and such longitudinal movement of the boiler as may be induced by its expansion and contraction under the influence of changes of temperature is admitted by means of links, by which the furnace is connected, near its front and rear ends, to pins resting in sockets bolted to the frames. The springs of the front or main driving axle are arranged in the usual manner, and their rear hangers are connected to equalizing bars located below the frames.

The springs of the rear axle are placed behind the pedestals and below the frames, their hangers being connected to the lower frame braces, and the weight transmitted to the rear driving boxes is borne by long equalizing bars, resting on pins on the tops of the boxes, and having hangers at their ends, connected respectively to the centres of the rear springs and to the back ends of the main equalizing bars. The arrangement is simple in its structure and conveniently located, and the remarkably easy riding of these engines, at speeds of 60 miles and over per hour, indicates the action of the springs to be properly and efficiently exerted.

The boiler is fed by two No. 9 Sellers injectors, the duty of each of which is rated by the makers at 45 gallons per minute, and the capacity of the tender is 4500 gallons of water and 10,000 pounds of coal, which admits of making the run from Philadelphia to Jersey City, 89·4 miles, without the necessity of stoppage for water, whilst sufficient fuel is taken for the round trip. The driving and truck wheels have steel tires, and the running gear is of the standard American construction and does not therefore require special notice. Facilities are embodied for oiling bearings from the cab, and also for turning water upon bearings from the tank.

The general dimensions of engine 411 are as follows:

Cylinders,	21 ins. diam., 22 ins. stroke.
Driving wheels,	diam. 5 feet 8 ins.
Centre to centre of driving axles,	7 feet
Truck wheels,	diam. 33 ins.
Boiler,	diam. 58 to 52 ins.
Number of tubes,	184
Diam. "	2 ins.
Length "	10 feet 2½ ins.
Length of furnace,	9 feet 6 ins.
Width "	8 feet.
Grate area,	76 sq. feet.
Heating surface of flues,	982 "
" " furnace,	135 "
Total heating surface,	1117 "
Smoke stack, diam.,	21 ins.
" " height,	48 ins.
Exhaust, single nozzle (variable),	3¾ to 5¾ ins. diam.
Total weight of engine,	98,200 pounds.

Weight on drivers, . . 64,250 "
Wheel base, ... 21 feet 1 in.

The service in which the passenger engines of this class are employed involves the necessity of developing extremely high speed, and of hauling heavy as well as light trains; the following details of their performance will indicate the nature and extent of their duty and capabilities.

In June, 1880, engine 506 hauled 15 passenger cars, carrying nearly 900 passengers, from Philadelphia to Bound Brook, the ruling gradient being 59 feet rise per mile, at an average speed of 42 miles per hour, the aggregate weight of train and passengers, exclusive of engine and tender, being in excess of 360 tons. The average consumption of fuel per mile was 62 pounds, or at the rate of 34¼ pounds per hour for each square foot of grate.

In July, 1880, engine 411 hauled 10 fully loaded passenger cars from Philadelphia to Bound Brook (59·2 miles) in one hour and nineteen minutes, making the usual slowing over two miles of bridging, the average consumption of fuel being 54 pounds per mile or 32 pounds per hour per square foot of grate.

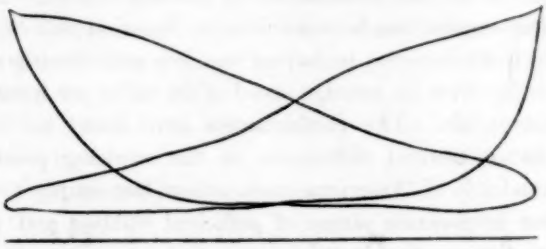


Fig. 6.

The indicator diagram, Fig. 6, was taken on engine 411 on the 20th of December, 1880. The day was one of the coldest of the season, the thermometer marking 6 degrees below zero (Fahr.); the train consisted of four well filled passenger cars. Notwithstanding the unfavorable influence of a brisk north wind, a speed of 72 miles per hour was attained upon a level while cutting off steam at 8⅝ inches. Several miles were run continuously in less than 50 seconds. The diagram, the vertical scale of which is 80 pounds to the inch, was taken at a speed of 72 miles per hour (or 360 revolutions per minute) with a boiler pressure of 105 pounds and cutting off at 8⅝ inches.

The diagram, Fig. 7, was taken on the same engine, May 4th, 1880. The train consisted of seven passenger cars, and the speed at the time of taking the diagram was at the rate of 64 miles per hour; boiler pressure 123 pounds, and point of cut off 6½ inches.

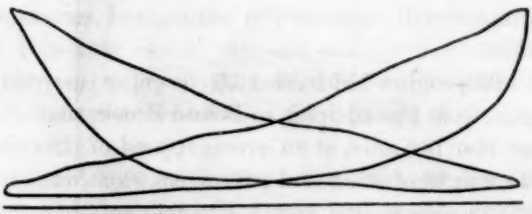


Fig. 7.

The engines above referred to, as well as others of similar design on the Bound Brook Division of the P. & R. R.R., are daily making four trips between Bound Brook and Philadelphia, aggregating 240 miles per day, yet so extremely gentle is the draught of the furnace that it is only occasionally that it becomes necessary to thoroughly clean the fire before the termination of the day's work. The regular schedule time on fast line between Wayne Junction and Bound Brook (54·9 miles) is 64 minutes, including one stop and slowing down three times. This involves an average speed of 56 miles per hour for nearly 55 continuous miles. The performances here noted are not in any manner due to essential differences in the working parts from the ordinary standards of American construction, but simply to the ability of the boiler to generate steam of sufficient volume and pressure to comply with the exacting requirements of the service referred to.

In the run from Philadelphia to Bound Brook there are ten miles of the line having ascending gradients varying from 15 to 30 feet per mile, eleven miles having ascents varying from 30 to 40 feet per mile, and one and a-quarter miles having an ascent of 59 feet per mile; twelve miles of the line are practically level, and there are twenty-five miles of descending gradients varying from 6 to 37 feet per mile. The four miles from Ninth and Green streets to Wayne Junction, being within city limits, are run at such restricted speed as to require eleven minutes to traverse the distance.

The engine shown in Fig. 8, which is reduced from a full page engraving in the *Railroad Gazette*, is one of thirty of the consolida-

tion type, having the Wootten boiler, which were built by the Baldwin Locomotive Works, and are now in coal train service on the Philadelphia and Reading Railroad. These boilers are similar in construction to that of the passenger engine before described, differing therefrom

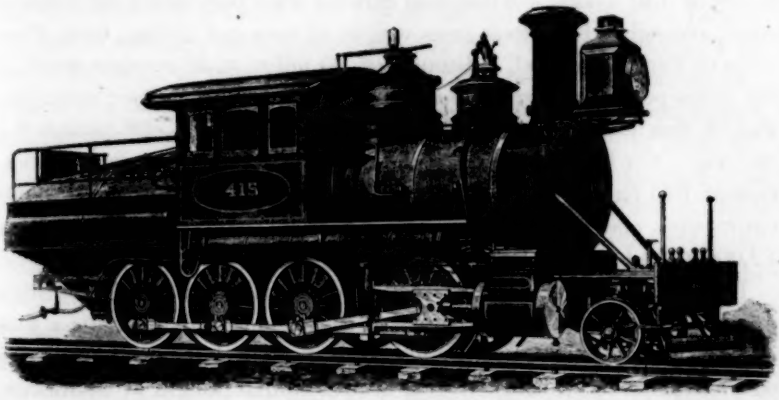


Fig. 8.

only in dimensions and in being fitted with feed-water heaters. The principal dimensions of the engines are as follows:

Cylinders,	20 ins. diam. x 24 ins. stroke.
Driving wheels,	diam. 50 ins.
Truck, "	" 30 ins.
Driving wheel base,	14 ft. 9 ins.
Total wheel base,	22 ft. 10 ins.
Fire box, length inside,	9 ft. 6 ins.
" width "	8 ft. 0 ins.
Grate surface,	76 sq. ft.
Boiler, diam.,	59 to 53 ins.
Number of tubes,	197
Diameter "	2 ins.
Length "	11 ft. 6½ ins.
Heating surface of tubes,	1190 sq. ft.
" " fire box,	167 sq. ft.
Total heating surface,	1357 sq. ft.
Driving wheel journals,	7x8 ins.
Truck " "	5x8 ins.
Steam ports,	16x1¼ ins.
Exhaust "	16x2½ ins.

Total weight of engine, . 103,000 pounds.
Weight on drivers, . . 90,000 pounds.
Two No. 8 Sellers injectors for supplying boiler.

In ordinary service the duty of the consolidation engines is to haul trains of 140 loaded 4-wheel coal cars (or their equivalent in 8-wheel cars), averaging 1120 tons gross weight of cars and lading, from Palo Alto to Port Richmond, a distance of 95 miles, at an average speed of ten miles per hour, over level and descending grades. Their consumption of fine anthracite coal in this service averages 11,500 pounds for the trip. On the return trip of 95 miles, in which distance an elevation of 625 feet has to be overcome, the load of these engines is 160 empty cars, and the weight of fine anthracite coal consumed is about 12,000 pounds.

In the month of September last a comparative test was made with one of these engines and an engine of the same type, but having a furnace of the ordinary construction, both engines burning bituminous coal and hauling coal trains of as nearly similar weight as attainable. The relative economy of the respective boilers will appear by the following statement; the distance run in each case was 110 miles daily:

	Consolidation Engine with ordinary boiler.		Consolidation Engine with Wootten boiler.	
Miles run per trip, . .	110½	110½	110½	110½
Coal used per trip, pounds	10,756	10,804	8,530	7,577
Coal used per mile, pounds	97·3	97·7	77·2	68·5
Water used per trip, gallons	8,871	8,341	9,198	8,305
Water evaporated per pound of coal, pounds, . . .	6·87	6·35	8·74	9·13

Showing reduced consumption of fuel equal to 25 per cent. and an increased evaporative efficiency of 35 per cent. in favor of the Wootten boiler.

The relative quantities of prepared coal of ordinary merchantable sizes and of the mine waste, consumed respectively by locomotives of the usual type and by those having the Wootten boiler, are shown by the following data of their performance, viz.:

In 27 days freight train service.

10-wheel engine, ordinary furnace, burned 110 tons broken coal.
" Wootten " " 113 " waste "

In 6 days coal train service.

10-wheel engine, ordinary furnace, . . . 30 tons steamboat coal.
Consolidation engine, Wootten furnace, . 33 " waste "

In 42 days coal train service (on gradients 90 ft. per mile).

10-wheel engine, ordinary furnace,	. .	313 tons lump coal.
Consolidation engine, Wootten furnace,	.	314 " waste "

The economic value of the boiler will be apparent from the fact that the difference between the cost of the fuel used in this furnace and that of ordinary marketable coal, such as is used generally in locomotive furnaces, is two dollars and ten cents per ton; it follows that if there is a daily consumption of 4½ tons of combustible per engine, each locomotive fitted with this boiler will effect a saving of $9.45 per day, a sum quite sufficient for its repair and perpetuation. The exemption from emission of sparks and cinders from the stack, which is noted in the report of the Alta Italia tests before referred to, and which is an obvious consequence of the lighter exhaust under which the enlarged fire box can be operated, while a subordinate feature, is one of material importance. A long series of failures marks the record in the matter of spark arresters, and in this department, as with many other efforts to remedy the evils of defective construction or abnormal operation, the old adage that "prevention is better than cure" is of peculiar application.

An article on "American High Speed Locomotives," published in the London *Engineer* of February 11th, 1881, referring more particularly to the Wootten engine, contains a number of statements which American engineers cannot fail to find both novel and amusing and may be here noticed in comparison with the Italian report, as illustrating the widely different conclusions arrived at, on the one hand, by an intelligent examination and carefully conducted practical test, and, on the other, by a cursory review of drawings and descriptions, evidently made with an insufficient understanding of the subject matter, and seemingly under the limitations of some little prejudice. Characterizing the Wootten engine as "abnormal in design," the article proposes to consider "why it is"; no explanation is, however, given, either of the element or elements of the design that are alleged to be "abnormal," or of the reasons upon which the opinion is based. The statements which are made, that two classes of the engine are built, in one of which "there is only one pair of drivers," and that "perforce Mr. Wootten was compelled to use single drivers," seem surprising, in view of the statement of Mr. Wootten to the writer that he never contemplated the application of a furnace upon his plan in

connection with single drivers, and is wholly unaware of such an engine having ever been made. The assertion that "the road may be regarded as level, the inclines compensating each other," embodies an error of fact, as may be seen from the statement of the profile of the road hereinbefore given, and the assumption as to "compensating" inclines being equivalent to a level, will scarcely be concurred in, either by those who construct railroads or those who operate them.

After a series of calculations, based upon data which the author of the *Engineer* article admits he has no definite or accurate knowledge of, and which appear to be intended to prove that the actual performance of the engine was not equal to that which had been assigned to it, the proposed disclosure of the "abnormal" design is abruptly abandoned in terms by the statement that "We do not propose here to say anything concerning the Wootten locomotive, either as a vehicle or an engine."

The article then proceeds to inform American engineers that until they "give up anthracite coal they will never attain perfection in fast locomotives," and that "English engineers will tell them, to a man, that unless anthracite coal can be burned in a furnace of less dimensions than that used by Mr. Wootten it had better not be burned at all in a fast locomotive." Leaving us wholly in ignorance of the grounds on which these remarkable dicta are based, the article concludes with the oratorical statement that "It is generally conceded that the boilers are the worst things about American locomotives, but without good boilers there can be no really express work done on a railway." Conceding the latter portion of the statement as undeniable, it is mildly suggested that there may be room for a difference of opinion as to the former, and inasmuch as the only "abnormal" feature of the Wootten boiler which appears, even by implication, is the fact that, in accordance with its design, it uses anthracite as fuel, it is probable that American engineers, many of whom are troubled with a large supply of this somewhat useful article, will be sufficiently indulgent to pass the peculiarity objected to without very severe condemnation, and doubtless, some will be found who will even agree with the engineers who conducted the Alta Italia tests in the opinion that the excellent qualities of anthracite coal make it a very desirable fuel for locomotive engines.

THE EFFICIENCY OF THE ENGINES OF THE STEAMER "ANTHRACITE."

By C. R. ROELKER, Passed Assistant Engineer, U. S. Navy.

We possess so few complete and reliable records of trials with steam machinery which can be used for an investigation of the various influences affecting the efficiency of steam in an engine that all additional experimental data relating to this subject should be thoroughly analyzed. The data furnished by the carefully conducted trial of the machinery of the steamer *Anthracite*, made in August, 1880, at the New York navy-yard, possess special interest because the means by which modern steam engineering seeks increased economy, viz.: high initial steam pressure and a high degree of expansion—were carried in this case to a limit which had not been heretofore approached. A full account of this trial and of the results obtained has been given in a paper "On the Experiments with the Perkins Machinery of the Steam Yacht *Anthracite*," published in No. 1, 2 and 3 of the current volume of the FRANKLIN INSTITUTE JOURNAL. In this paper the discussion of the action and efficiency of the steam in the engine is based on a comparison of the weights of water evaporated in the boiler, found by actual measurement, and of steam condensed in the different cylinders, calculated from indicator diagrams. But the weight of steam expended is not an exact measure of the efficiency of an engine, and, besides, the method by which the work done by the steam and the weight of steam condensed in the cylinders is calculated is, to say the least, unusual. These considerations have induced the writer to present the following discussion of the efficiency of the *Anthracite's* engines in this trial, as measured by the number of units of heat expended in the engines, so that the results of this trial may be directly comparable with those obtained in other steam engine trials.

The calculations in this paper are based on the data recorded in the published official report of this trial. It must, however, be observed that the *total horses-power* developed in each cylinder are computed in the usual manner for the mean absolute pressure on the *whole* area of the piston. Further, the *indicated horses-power* developed in the first

or small cylinder is not calculated from the mean ordinate of the indicator diagrams taken from the top of that cylinder, but for the difference between the mean absolute steam pressure in that cylinder during the down stroke of the piston and the mean back pressure acting on the under side of the piston during that stroke; in this manner the actual gross effective power developed during the down stroke of the piston in that cylinder is found. In like manner, the *indicated horses-power* developed in the second or intermediate cylinder are calculated for the difference between the mean absolute pressure on the piston of that cylinder during the upstroke and the mean back pressures acting on the upper side of the piston of the small cylinder and on the annular surface of the piston communicating with the receiver. Thus we get the following quantities:

Total horses-power developed in first cylinder,	28·8902
Total horses-power developed in second cylinder,	31·8339
Total horses-power developed in third cylinder,	52·9109
Indicated horses-power developed in first cylinder,	23·2280
Indicated horses-power developed in second cylinder,	5·1000
Indicated horses-power developed in third cylinder,	39·4483

For other data used in the following calculations the reader is referred to the published official report. In order to make the results obtained in the present investigation comparable with those given in the above mentioned paper relating to this trial, the same constants have been used in these calculations as in the former paper: for this reason the mechanical equivalent of one Fahrenheit unit of heat is taken at 789·25 foot pounds.

1. Units of heat generated in the boiler per hour, . 1,642,983

First, or Small, Cylinder.

2. Units of heat equivalent to indicated horses-power developed in first cylinder, per hour, . . 58,271
3. Units of heat equivalent to total horses-power developed in first cylinder, per hour, . . 72,477
4. Units of heat in the steam discharged from first cylinder at the end of the stroke of its piston, less the units of heat in an equal weight of feed-water, per hour, ... 620,711

5. Units of heat in the condensed water present in the first cylinder at the end of the stroke of its piston, less the units of heat in an equal weight of feed water, per hour, ...	174,035
6. Units of heat expended in radiation, conduction, etc., and in re-evaporation at the end of the stroke, in the first cylinder, per hour, . . .	775,760
Second, or Intermediate, Cylinder.	
7. Units of heat equivalent to indicated horses-power developed in second cylinder, per hour, . .	12,794
8. Units of heat equivalent to total horses-power developed in second cylinder, per hour, . .	79,861
9. Units of heat in the steam discharged from second cylinder at the end of the stroke of its piston, less the units of heat in an equal weight of feed-water, per hour, ...	809,855
10. Units of heat in the condensed water present in the second cylinder at the end of the stroke, less the units of heat in an equal weight of feed-water, per hour,	87,738
11. Units of heat expended in radiation, conduction, etc., in first and second cylinders, and in re-evaporation at end of stroke of piston in second cylinder, per hour,	607,258
Third, or Large, Cylinder.	
12. Units of heat equivalent to indicated horses-power developed in third cylinder, per hour, . .	98,964
13. Units of heat equivalent to total horses-power developed in the third cylinder, per hour, . .	132,736
14. Units of heat in the steam discharged from the third cylinder at the end of the stroke of its piston, less the units of heat in an equal weight of feed-water, per hour, ...	1,144,020
15. Units of heat in the condensed water present in the third cylinder at the end of the stroke, less the units of heat in an equal weight of feed-water, per hour,	21,342
16. Units of heat expended in radiation, conduction, etc., in first, second and third cylinders, and in re-evaporation at end of stroke of third cylinder, per hour, .	273,820

In computing the units of heat transmitted to the feed-water in the boiler, per hour (1), it has been assumed that the steam was dry and saturated in the boiler. The temperature and dryness of the steam were not ascertained during the trial by thermometric and calorimetric tests; but the board which conducted this trial has based the calculations given in the report on the same assumption. The total heat of the feed-water is taken at 120·63 Fahrenheit units, and the total heat of the boiler steam is taken at 1242·03 units, above the Fahrenheit zero.

Since a careful examination of the pistons and valves under pressure revealed no leakage of steam it is assumed that, at the end of each stroke, the whole weight of water vaporized in the boiler during the corresponding time was present in each cylinder. The weight of steam discharged from the cylinder at the end of the stroke is calculated by multiplying the space displaced by the piston per stroke plus the space in the clearance and steam passage, by the density of steam corresponding to the final pressure in the cylinder, and subtracting the weight of steam filling the clearance and steam passage at the moment the steam valve begins to open. The units of heat present in this weight of steam above the heat of the feed-water (4, 9, 14) are found by multiplying this weight of steam by the total heat of steam of corresponding pressure above the heat of the feed-water, less the quantity of heat expended in overcoming external resistance in vaporizing the feed-water under the pressure obtaining at the end of the stroke.

The difference between the weight of steam found to be present in the cylinder at the end of the stroke and the weight of water vaporized in the boiler is called the weight of condensed water present in the cylinder at the end of the stroke for the unit of time, and it includes the weight of steam admitted to the jacket-coils during the same time. It is to be regretted that the weight and temperature of the water discharged from the jacket-coils were not measured in the experiment. In computing the units of heat present in the condensed water in each cylinder (5, 10, 15) it is assumed that all this water had the temperature of the saturated steam at the end of the stroke of the piston in the respective cylinder. Strictly speaking, this assumption is not correct, since the pressures and temperatures in the jacket-coils of the different cylinders differed probably from those in the cylinders at the end of the stroke; but the resulting error is necessarily small.

This error makes the quantities of heat expended in radiation, re-evaporation, etc., as given above, a little too large, and the quantities of heat contained in the water present in the cylinder and in the jacket, at the end of the stroke, a little too small.

The quantities of heat given as expended in radiation, conduction, etc. (6, 11, 16), are simply the quantities left after deducting from the total heat transmitted to the feed-water in the boiler the sum of the quantities of heat given as being present in the steam and water in the cylinders and of the heat transmuted into power. The neglect to measure the weight and temperature of the water discharged from the jackets makes a further analysis of these quantities impossible. If the steam generated in the boiler should have been either moist or superheated, instead of dry saturated as assumed, the quantities given in 6, 11 and 16 would, of course, be correspondingly less or greater. A relatively small portion of this heat is actually lost by radiation, conduction and vibrations; the larger portion is expended in warming the walls of the cylinders cooled during the previous return-stroke by the vaporization of water deposited upon them; and, in consequence of a like process, this heat re-appears and is available for work in the second and third cylinders, but is discharged from the third cylinder into the condenser. The absorption of heat due to this cause in the larger cylinders is greatly less than in the smaller cylinder, because in the larger cylinders the range of temperature of the steam and the ratio of the superficial area of the walls to the volume of the cylinder is greatly less, and the temperature of the steam entering the jacket relatively to the mean temperature of the steam in the cylinder is greater than in the smaller cylinders.

Of the heat transmuted into external work only that portion which is equivalent to the indicated horses-power developed in those cylinders has permanently disappeared, the remainder is expended in overcoming the resistance of the steam acting on the opposite side of the piston and causes an equal amount of energy to re-appear in this steam, which becomes available in the second and third cylinders respectively.

After the steam has completed its expansion in the third cylinder when the piston has arrived at the end of its stroke, 78·54 per cent. of the total weight of water vaporized in the boiler is present in this cylinder in the form of steam, the remaining 21·46 per cent. being condensed in this cylinder and in the jacket. Of the total heat transmitted to the water in the boiler 70·93 per cent. are found to be pre-

sent in the steam and water filling the third cylinder and the jacket-coil; 12·40 per cent. have been transmuted into external work represented by the indicated horses-power developed in the first and second cylinders and the total horses-power developed in the third cylinder; and 16·67 per cent. have been lost through radiation, conduction, etc., in the passage of the steam from the boiler to the end of the stroke in the third cylinder, and through the abstraction of heat from the walls of this cylinder during the exhaust-stroke by the re-evaporation of the water deposited upon them. Besides this latter quantity (the amount of which we cannot determine from the data of the experiment) there is discharged into the condenser the whole of the heat given as being present in the steam and water filling the cylinder at the end of the stroke of the piston plus the heat equivalent of the difference between the total and indicated horses-power developed in the third cylinder (if we neglect the small amount of work done during compression), or [70·93 + 2·06 =] 72·99 per cent. of the total heat transmitted to the water in the boiler.

The quantity of heat transmuted into mechanical work represented by the indicated horses-power developed by the engines is 10·34 per cent. of the total heat of evaporation, and this represents the *actual efficiency* of the engines.

The *relative efficiency* of the engines is found by comparing their actual efficiency with the greatest efficiency theoretically attainable in a steam engine working with saturated steam of the same boiler pressure and with the same temperature of feed-water and transforming all the heat expended (except the quantity necessarily discharged into the condenser) into mechanical work. Such a comparison will enable us to determine what increase of efficiency can possibly be obtained by changes in the practical working of the engines.

In a "perfect reversible heat-engine," working between the limits of temperature given by the boiler pressure and the temperature of the feed-water in the experiment under consideration, the efficiency would be represented by $\left[\frac{426{\cdot}3 - 461{\cdot}2}{426{\cdot}3 + 120{\cdot}5} =\right]$ 34·46 per cent. of the total heat generated.

Since, however, one condition of the property of reversibility in a perfect engine—viz.: that the temperature of the working fluid be raised by compression to the initial temperature, before it is delivered into the boiler—is not realized in our present type of the steam engine, its

efficiency is correspondingly diminished. The loss of efficiency due to this cause, computed by the formula given by Cotterill, is, in the present case, 4·04 per cent. of the total heat of evaporation. Hence, in a perfect steam engine, working with the same boiler pressure and feed-water temperature as in the experiment under consideration [34·46 — 4·04 =] 30·42 per cent. of the total heat of evaporation would be transformed into indicated horses-power and 69·58 per cent. would be discharged into the condenser; and the *relative efficiency* of the *Anthracite's* engines was $\left(\frac{10{\cdot}34 \times 100}{30{\cdot}42} =\right) 33{\cdot}99$ per cent.

The loss of efficiency, represented by [30·42 — 10·34] = 20·08 per cent., is due to (1) the excess of back pressure in the third cylinder above the pressure corresponding to the temperature of the feed-water; (2) the incomplete expansion of the steam, which in the perfect engine is continued till the final pressure is equal to the pressure corresponding to the temperature of the feed-water; (3) the loss of heat by radiation, conduction, re-evaporation of water in the cylinder, etc. By calculation we find the following values for these several losses, expressed in per cent. of the total heat transmitted to the feed-water in the boiler, viz.:

(1) Loss due to excess of back pressure, .	1·30 per cent.
(2) Loss due to incomplete expansion, .	3·55 per cent.
(3) Loss due to radiation, re-evaporation, etc., .	16·67 per cent.
Total loss, . . .	21·52 per cent.

The difference [21·52 — 20·08 =] 1·44 per cent. is due to inaccuracies in the computations and in the constants used, but mainly in the observations made. We may safely conclude that the loss due to radiation, re-evaporation, etc., as given is somewhat too great, either for the reason given above, or because the total quantity of heat transmitted to the feed-water in the boiler was somewhat less than we have assumed it to be, on account of a small percentage of moisture contained in the steam.

The excess of back pressure in the experiment amounted to 2·675 pounds. It is practically impossible to prevent this excess entirely. Assuming that this excess can be reduced to 1 pound the resulting gain in efficiency will be 0·814 per cent.

The unavoidable excess of back pressure will reduce still further the small gain theoretically possible from completing the expansion of the steam. It appears likely that, in the present case, any gain in

efficiency resulting from the use of a higher degree of expansion would be accompanied by equal or greater losses of heat by conduction and re-evaporation, by friction, etc.; consequently, we must conclude that the loss of efficiency due to incomplete expansion cannot be diminished.

The loss of heat due to external radiation and conduction has been determined directly in several experiments with different engines, and has beeen found to vary between 1·5 and 2·5 per cent. Assuming a mean value of 2 per cent. for this loss in the present case, and that the quantity of heat actually lost by external radiation and re-evaporation was 1·44 per cent. less than the quantity given above, we have a loss of [16·67 — 1·44 — 2·00] = 13·23 per cent. due to the transmission of heat from the walls of the third cylinder during the exhaust stroke. This loss may be greatly diminished by efficient steam-jacketing and superheating; it is, however, doubtful whether this loss can be reduced to less than 4·5 per cent. under favorable conditions of practice. Assuming this amount of loss to be unavoidable, we find that the greatest gain in efficiency which may be obtained under more favorable conditions of working in the *Anthracite's* engines is equal to [13·23 — 4·5 + 0·814] = 9·544 per cent. of the total heat transmitted to the feed-water, or 92·3 per cent. of the actual efficiency of the engines.

The large amount of condensation in the first cylinder indicates that the steam may be superheated in the boiler to a considerable degree without producing injurious effects in the engines. To reduce materially the "exhaust waste," or loss from re-evaporation, in the third cylinder, it will probably be necessary to dry or superheat the steam in the receiver before it enters the third cylinder. Such a method of treating the steam in a compound engine was recommended many years ago by Hirn, and has been practically tried in several instances in France.

No account has been taken in the preceding investigation of the heat produced by the friction of pistons and valves, as no safe estimate can be made of its quantity, which is but small at all events.

The very unequal development of the indicated horses-power in the different cylinders was likely prejudicial to the economical performance of the engines. It is desirable that in future trials of these engines attention be given to a more equal distribution of the indicated power among the different cylinders.

AN ACCOUNT OF THE EXPERIMENTS MADE IN MULHOUSE, GERMANY, BY A COMMITTEE OF THE INDUSTRIAL SOCIETY OF THAT CITY, ON A CORLISS STEAM ENGINE, TO DETERMINE ITS ECONOMIC PERFORMANCE WITH AND WITHOUT STEAM-JACKETING.

By Chief Engineer ISHERWOOD, U. S. Navy.

The experiments described in this paper were made by a committee of the Industrial Society of Mulhouse, in Alsace, Germany, on a Corliss engine that had been about six months in use driving the looms of the factory of Messrs. Schlumberger & Co., in that city. The committee consisted of twelve persons, one of whom was a member of the firm which constructed the engine, and their report will be found on pages 910 to 931 of the Bulletin of the Society for 1878.

The cylinder of the engine experimented with was not only steam-jacketed on the sides and both ends, but its piston was made hollow and filled with steam of the boiler pressure, like the jackets of the cylinder, in order that the application of steam-jacketing might receive its utmost extension. The boiler furnished saturated steam. Neither the idea nor the execution of this method of converting the piston into a steam jacket was new, nor were the experiments made to ascertain its effect upon the economic performance of the engine a novelty, as precisely the same had been done in the city of New York by Henry Waterman, in 1864, an account of whose engine, and a complete detail of the experiments made with it, were given in a memoir by the writer to the Bureau of Steam Engineering in the Navy Department of the United States, and published as an appendix to the report for 1875 of the chief of that bureau to the Secretary of the Navy.

The experiments made by the Committee of the Industrial Society of Mulhouse are much inferior to those made by Waterman, in number, importance, variety, length and completeness, but they have the advantage of being made on a greatly larger engine, and one whose valve gear is considered by many to be peculiarly adapted for the economic use of steam.

Instead of furnishing a translation of the report of the committee, which would be of but little use to the American engineer, the writer has taken their observations, recalculating the quantities and correcting them where necessary, following his own arrangement entirely and giving his own deductions, his purpose being to present the data and results of the experiments in the most compact form and yet include every fact ascertained.

Engine.

There were two Corliss engines, each of one cylinder, connected to the same main shaft, but only one engine was experimented with; the other, however, was kept in operation at the same time for the purpose of maintaining a uniform number of revolutions of the main shaft per minute, which was necessary for the work of the factory, during the variable loads employed with the engine under course of experiment.

The cylinder was horizontal, and connected directly to the main shaft, which carried a toothed fly wheel gearing into a pinion, the pitch line diameters of the two comparing as 192 and 65. The diameter of the pitch circle of the fly wheel was $16\frac{2}{3}$ feet. The fly wheel shaft was $8\frac{1}{3}$ feet long and $11\frac{2}{3}$ inches diameter. The shaft of the pinion wheel was $6\frac{2}{3}$ inches diameter and $35\frac{1}{2}$ feet long up to its coupling with the shafting of the factory. The cylinder had the following dimensions:

Diameter of cylinder,	24 inches.
Diameter of piston-rod (both sides of piston),	$3\frac{5}{8}$ inches.
Stroke of piston,	48 inches.
Net area of piston,	442·0698 sq. ins.
Space displacement of piston per stroke,	12·279717 cu. ft.
Clearance,	0·3937 inch.
Space in clearance at one end of cylinder,	0·100193 cu. ft.
Space in steam passages at one end of cylinder,	0·202470 cu. ft.
Total space in clearance and steam passages at one end of cylinder,	0·302663 cu. ft.
Fraction of the space displacement of the piston per stroke in clearance and steam passages at one end of cylinder,	0·024647
Ratio of length of connecting rod to length of crank, between centres,	5·
Face of piston,	$6\frac{1}{4}$ inches.

Aggregate width of the two packing rings in the piston, ... $1\frac{1}{2}$ inches.
Width in clear between the cylinder and its steam jacket, ... $3\frac{1}{4}$ inches.
Thickness of metal of cylinder, . . $1\frac{1}{4}$ inches.
Thickness of metal of jacket, . . $1\frac{3}{8}$ inches.

The sides and ends of the cylinder were steam jacketed, the jackets being cast in one piece with the cylinder, and with its ends, both of which latter were bolted on. All the jackets communicated and were drained of their water of condensation by a pipe with an automatic valve, and also by a valve to be worked by hand at will.

The piston was steam jacketed as well as its cylinder, that is to say, it was cast hollow and had its interior filled with steam through a horizontal tube of $\frac{3}{4}$ inch interior and $1\frac{1}{4}$ inch exterior diameter, one end of which was screwed into the piston as near as possible to the upper end of its vertical diameter. This tube passed through one end of the cylinder, by means of a stuffing-box, into a receptacle or closed case outside of the cylinder, by means of another stuffing-box. The case was filled with steam directly from the jackets of the cylinder, through a small pipe, and from the case the steam passed through the tube into the interior of the piston, the tube moving with the piston forward and backward, and passing air and steam-tight through the two stuffing-boxes. By a precisely duplicate arrangement, the water of condensation was drained from the interior of the piston, the horizontal drain tube being screwed into the piston as near the lower end of its vertical diameter as possible, passed through a stuffing-box in the end of the cylinder, and then through another stuffing-box in the end of a case or receptacle; the water of condensation being thus discharged into the case was thence carried off by a small vertical pipe, fitted with a stop cock.

The piston rod, with uniform diameter, extended through the piston, and through both ends of the cylinder by means of stuffing-boxes.

The cylinder had four valves, two for the steam and two for the exhaust; the former were at the highest point of the cylinder, the latter were at the lowest. They were cylindrical and worked in cylindrical seats with a vibrating motion. The steam valves were also the cut-off valves, the point of cutting off being variable and controlled by the governor of the engine, which acted directly on them.

All the steam jackets were supplied with steam directly from the boiler, and had no connection with the valve chests or cylinder.

The engine was fitted with a jet condenser placed beneath the cylinder. The air-pump was horizontal and its piston received its movement from a vertical lever or half beam supported in a pillow block at its lower end. This half beam was worked by means of a short link connecting it with the crosshead. The feed pump was also horizontal and operated in the same manner.

The cylinder with which the experiments were made was supplied with saturated steam by a boiler which was exclusively employed for that purpose. Another boiler supplied the other cylinder, and between these boilers there was no communication. The experimental cylinder was connected to its boiler by a steam pipe 80 feet in length and 6 inches in outside diameter. This pipe inclined strongly upwards after leaving the top of the steam drum of the boiler, so that any water entrained into it from the boiler by the steam, or any water of condensation in it due to external refrigeration, would run back to the boiler by gravity.

The cylinder and steam pipe were well protected from losing heat by radiation, being covered with non-conducting material.

The cylinder valves had neither steam lead, nor exhaust lead, nor cushioning.

The Experiments.

The main purpose of the committee was to ascertain for the engine in question the cost of the indicated horse-power in pounds of feed water consumed per hour when no steam was present in either the jackets or in the piston of the cylinder; when steam was present in the cylinder jackets but not in the piston; and when steam was present both in the cylinder jackets and in the piston. Throughout all the experiments the piston speed and the boiler pressure were to be maintained as nearly constant as possible, with the throttle valve wide open; but in each of the three cases the engine was to develop different indicated horses-power by cutting off the steam at different fractions of the stroke of the piston, the constant speed of the piston being maintained by the help of the duplicate engine connected to the same shaft. The determinations of the cost of the indicated horse-power in the different cases, and for the same number of horses-power developed, gave the economy due to the presence of steam in the cylinder jackets alone, and in the cylinder jackets and piston combined.

The experiments made with the same piston speed, boiler pressure, and position of throttle valve, either with or without steam in the jackets and piston of the cylinder, gave, incidentally, the economical effect, under strictly comparable conditions, of the different measures of expansion with which the steam was used, though this determination was no portion of the intention of the committee, who, in their conclusions, utterly ignore any difference in the economic result of the different measures of expansion, assuming, apparently, the economy to be the same with all.

Twelve experiments were made: three without steam in either the cylinder jackets or piston; one, accidentally, with the jackets partly filled with steam and partly filled with the water of its condensation, owing to the incomplete drainage of the latter; two with steam in the jackets of the cylinder but not in the piston; and six with steam in the cylinder jackets and piston. The measure of expansion with which the steam was used varied from 5·7037 to 12·3978 times. The boiler pressure averaged 68·2480 pounds per square inch above the atmosphere, and the number of double strokes made by the piston averaged 49·8925 per minute for the different experiments. The steam pressure in the valve chest of the cylinder averaged 3·5 pounds per square inch less than in the boiler, and the steam pressure in the cylinder at the commencement of the stroke of the piston averaged 6·827 pounds per square inch less than in the valve chest, owing to the smallness of the steam ports, making the pressure on the piston at the commencement of its stroke 10·327 pounds per square inch less than in the boiler. This considerable difference of pressure must have given the steam on entering the cylinder about 8·5 degrees Fahrenheit of superheating.

Each experiment was intended to continue one working day of the factory, and such was the case with nine of them, which averaged 10·6371 hours; the remaining three, however, owing to accidents, continued only half days each, averaging 5·4765 hours.

A set of indicator diagrams, and a complete set of observations of the steam pressures in the boiler and in the valve chest of the cylinder, of the back pressure in the condenser, and of the temperatures of the injection and feed water, were taken every fifteen minutes. The temperature of the injection water was sensibly constant throughout at 50¼ degrees Fahrenheit.

Two indicators were employed, and had their springs carefully

tested at the temperature of use. They remained permanently in position, one at each end of the cylinder, and gave very consistent diagrams. The number of double strokes made by the piston was taken by a counter.

The feed water was delivered by the air-pump through a special pipe into two tanks, alternately, and its quantity therein ascertained. Each tank contained 106 cubic feet. The weight of water per tank was ascertained by weighing into the latter water of the temperature of the feed in quantities of 220 pounds at a time, and then repeating the weighing by drawing off the water as a check; a gauge placed at the side of the tank was thus graduated to intervals of 2·2 pounds, so that at any moment the exact quantity in the tank could be known by inspection. The cost of the power was measured by the pounds of feed water consumed per hour per horse-power.

The water of condensation from the jackets of the cylinder, and from the piston, were drained into small tanks and weighed separately from time to time during the experiments in quantities of 22 pounds.

The pressures were taken from carefully tested manometers. The observers were numerous, and each had his special observations to make. Every provision was made to secure strictly accurate results.

An experiment was made to ascertain by the indicator the pressure on the steam piston required to work the engine, *per se*, that is to say, the unloaded engine; the factory shafting being uncoupled for this purpose, so that the experiment determined the piston pressure absorbed by the friction of the engine, gearing and shafting up to the coupling when working with the shafting and looms of the factory disconnected.

After the shafting was uncoupled, the engine thus unloaded was worked thirty minutes at 52·102 double strokes of its piston per minute, during which time sixteen indicator diagrams were taken whose mean gave the pressure 2·1641 pounds per square inch of piston. As the resistance of the engine, gearing and shafting under these conditions was almost wholly frictional, and therefore uninfluenced by the speed of the piston, this pressure remains constant at all speeds of piston, and must be deducted from the indicated pressure when the engine is loaded in order to give the net pressure applied to the crank pin.

In addition to the above determination of the piston pressure required to work the unloaded engine, gearing and shafting up to the

coupling, the committee made another determination by means of two friction brakes placed on the pinion shaft as close to the coupling as practicable. From these brakes were ascertained the horses-power transmitted to the shafting beyond them, while the indicator gave simultaneously the indicated horses-power exerted by the engine. The subtraction of the first power from the last gave the power absorbed by the friction of the engine, the friction of the gearing, and the friction of the shafting up to the coupling, *per se*, and *also the friction produced by the load on these mechanisms;* consequently, the power obtained by the subtraction of the brake power from the engine power was greater than that due to working the unloaded mechanisms by the amount due to the friction produced by the load upon them. The friction resistances of an engine are of two kinds: one, the friction of the unloaded engine, due simply to the weight of its moving parts, and to the pressure of the packings of the pistons, piston-rods and valves; this friction is constant at all speeds of piston, and is wholly independent of the load, be the latter great or small; the pressure on the steam piston required to overcome it is the true pressure required to work the unloaded engine, *per se*, and should always be used to obtain the net pressure upon the crank pin by subtracting it from the indicated pressure. The other friction resistance of an engine is that which is due simply to the load, and is a constant proportion of the load, varying directly as the latter varies. Now the load is represented by the pressure on the crank pin, or net pressure, that is to say, by the difference of the indicated pressure and the pressure required to work the unloaded engine, so that the friction due to the load is a constant fraction of the net pressure or pressure on the crank pin, which pressure with the same engine is variable within very wide limits. It is evident that when the brakes were in action, the difference between the power shown by them and the indicated power exerted by the engine, included both kinds of friction resistance, for the load in that case was upon the engine, and the friction of the load had to be overcome as well as the friction of the mere weight of the mechanism and of the pressure of the packings. The only method by which the friction of the unloaded engine can be obtained is by throwing off the entire load and ascertaining by the indicator the pressure required to work the mechanism, *per se*.

The experiments with the brakes continued one hour and thirty-eight minutes, during which sixty-nine indicator diagrams were taken.

The mean speed of the piston was 49·64 double strokes per minute, from which the extremes varied by only one-third of a double stroke; and the pressure on the piston, due to the horses-power obtained by subtracting the brake power from the indicated power exerted by the engine, was 2·3452 pounds per square inch. The pressure due to working the unloaded mechanism, as given direct by the indicator, was 2·1641 pounds per square inch of piston, consequently the difference between that pressure and the pressure of 2·3452 pounds was due to the friction of the load, and is $\left(\frac{2{\cdot}3452 - 2{\cdot}1641 \times 100}{2{\cdot}3452} =\right)$ 7·722 per centum of the load. The friction coefficient due to the load alone has always been assumed by the writer for engines as habitually lubricated at 7·5 per centum of the load.

The data and results of the experiments will be found in the following table, carefully changed from the French into English measures. The data are the totals and means of all the indicator diagrams and of all the observations taken. This table contains all the reliable facts which can be obtained from the text, the tables and the indicator diagrams given in the report of the committee. That report is very meagre, leaving much to be supplemented and inferred, and were it not for the diagrams reproduced—one as a representative for each experiment—from which some important quantities could be taken, the experiments would lose much of their value. It is to be regretted that, with so convenient an arrangement of engines, and after such elaborate preparations, so few experiments were made and so few facts of interest reported. Even as regards the experiments actually made, some most important data are omitted. For instance: the steam pressures in the cylinder at the commencement of the stroke of the piston, at the point of cutting off the steam, and at the end of the stroke of the piston, are not given; neither is the mean back pressure against the piston, nor the back pressure against it at the commencement of its stroke; nor is even the indicated pressure given, nor the fraction of the stroke of the piston at which the steam was cut off. All these could be obtained from the indicator diagrams actually taken. What is given from them are only the indicated horses-power developed in the different experiments, and the horses-power required to work the unloaded engine, and from these the writer has calculated the indicated and net pressures in the different cases, while from the

representative diagrams he has taken the back pressure against the pistons and the point of cutting off the steam.

The pressure on the piston at the commencement of its stroke must be stated, and also the mean back pressure against it, in order that the pressures between which the engine worked may be known. The latter pressure is necessary, too, for ascertaining the total pressure on the piston—a most important quantity. The pressures at the point of cutting off the steam, and at the end of the stroke of the piston, together with the back pressure against the piston at the commencement of its stroke, and the point at which the steam was cut off in fractions of the stroke, are necessary for calculating the weight of steam present at those points in the cylinder, from which and the weight of water pumped into the boiler the cylinder condensation can be known, one of the most valuable of determinations and the only one which explains the economy derived from steam jacketing whose effect without such explanation is merely mysterious. A properly made set of experiments, and a proper report of them, not only gives *all* the facts in relation to the subject, but furnishes an elucidation of them, showing why they are as they are, and pointing out the producing and modifying causes. Had the committee submitted a simple table containing all the quantities it was possible to observe, and just as observed without corrections or deductions, others would have been enabled to make the necessary calculations and inferences which are now impossible. Nothing is more unsatisfactory than a report in which only the conclusions of the experimenters are given without a statement of the complete experimental facts and processes on which they are based. The experimental results in steam engineering are not absolute, but relative entirely to the mechanism and methods employed; hence the necessity for a complete description of both and a clear statement of all the quantities involved, whether bearing on the immediate views and purposes of the experimenters or not.

The committee in their report do not give the weight of feed water actually pumped into the boiler, nor the weight of the water of condensation actually drained from the steam jackets and piston of the cylinder; but they give these weights reduced to the temperature of 32 degrees Fahrenheit. That is to say, taking the product of the total heat imparted to the feed water in the boiler above its actual temperature on entering, into the the actual weight of that water, they

calculated what would be the weight of water given by dividing this product by the total heat that would have to be imparted to the feed water had its temperature on entering the boiler been 32 degrees Fahrenheit instead of the temperature it actually was, in order to convert it into steam of the boiler pressure. This quotient is a factitious quantity and misleading. It is not the weight of steam producing the power; that weight is independent of the temperature of the feed water and would be the same, other things equal, let the temperature of the feed water be what it might. The committee's calculated weight of water only represents relatively the units of heat that would have been imparted to the feed water on the supposition that its temperature was 32 degrees Fahrenheit, a perfectly useless piece of knowledge; what is required to be known are the units of heat that were actually imparted under the experimental conditions to the feed water. Different mechanisms and methods of using steam are necessarily accompanied by inseparable different temperatures of the feed water, and these are the temperatures which should furnish the bases for computation and not factitious or arbitrary ones. Accordingly, the writer has been obliged to re-obtain the true or experimental weights of feed water by taking the committee's factitious weights in the different experiments, and reversing the order of their calculations, employing in each case the experimental temperatures of the feed water and of the boiler steam; and these weights are given in the following table instead of the erroneous weights calculated by the committee. Nothing like this table will be found in the committee's report, but it contains all the facts which could be collected from the text, tables and indicator diagrams therein given.

For facility of reference, the quantities in the table have been arranged in appropriate groups: the description of the quantities on their respective lines is so full that no additional explanations are needed, save that the net pressures on the piston are in all cases the indicated pressures less 2·1641 pounds per square inch, which is the pressure required to work the unloaded engine; and that the total pressures on the piston are in all cases the sum of the indicated pressure on the piston and of the back pressure against it. Each experiment is designated by a capital letter placed at the head of the tabular column containing its data and results.

(To be continued.)

TABLE CONTAINING THE DATA AND RESULTS OF THE EXPERIMENTS MADE AT MULHOUSE, IN ALSACE, GERMANY, ON THE JACKETED
DETERMINE ITS ECONOMIC EFFICIENCY IN RAPPORT OF POWER TO WEIGHT OF STEAM CONSUMED UNDER THE DIFFERENT CON
PARTLY FILLED WITH STEAM OF BOILER PRESSURE AND PARTLY FILLED WITH ITS WATER OF CONDENSATION, BUT
PRESSURE, BUT NO STEAM IN THE PISTON; AND, FINALLY, OF THE CYLINDER JACKET

The piston speed and boiler pressure were nearly constant, but the steam was used with different measures of expans

		No steam in the steam jackets of the cylinder, nor in the steam-piston.		
		A	*B*	*C*
	Date of the experiments,	May 6th, A.M.	April 8th.	April 9th.
TOTAL QUANTITIES.	Duration of experiments in consecutive hours,	5·6814	10·7080	5·6772
	Total number of pounds of feed water pumped into the boiler,	13089·5382	35550·5679	18725·6027
	Total number of pounds of water of condensation drained from the steam jackets of the cylinder,	.....	.....	.....
	Total number of pounds of water of condensation drained from the steam-piston,	.....	.....	.....
	Aggregate number of pounds of water of condensation drained from the steam jackets of the cylinder and from the steam piston,	.....	.....	.....
	Per centum of the steam evaporated in the boiler condensed in the steam jackets of the cylinder,	.....	.....	.....
	Per centum of the steam evaporated in the boiler condensed in the steam-piston,	.....	.....	.....
	Aggregate per centum of the steam evaporated in the boiler condensed in the steam jackets of the cylinder and in the steam piston,	.....	.....	.....
	Total number of double strokes made by the steam-piston,	17019·	31605·	16762·
ENGINE.	Steam pressure in boiler, in pounds per square inch above the atmosphere,	67·7148	66·2072	67·1601
	Steam pressure in valve chests of cylinder, in pounds per square inch above the atmosphere,	64·1022	62·7072	63·6600
	Proportion of throttle valve open,	Wide.	Wide.	Wide.
	Fraction of stroke of piston completed when the steam was cut off,	0·0580	0·1050	0·1050
	Number of times the steam was expanded,	12·3978	7·9033	7·9033
	Pressure in the condenser in pounds per square inch above zero,	1·9907	2·0680	2·0880
	Temperature, in degrees Fahrenheit, of the feed water,	80·	83·	83·
	Number of pounds of feed water pumped per hour into the boiler,	2303·9283	3320·0007	3298·3870
	Number of double strokes made per minute by the piston,	49·9261	49·1922	49·2085
STEAM PRESSURES IN CYLINDER.	Steam pressure on piston at commencement of its stroke, in pounds per square inch above zero,	71·9630	70·5680	71·5210
	Mean back pressure against piston during its stroke, in pounds per square inch above zero,	2·9860	3·1020	3·1320
	Mean indicated pressure on piston during its stroke, in pounds per square inch,	15·2113	24·0281	24·3657
	Mean net pressure on piston during its stroke, in pounds per square inch,	13·0472	21·8640	22·2016
	Mean total pressure on piston during its stroke, in pounds per square inch,	18·1973	27·1301	27·4977
HORSES-POWER.	Indicated horses-power developed by the engine,	81·3881	126·6726	128·4950
	Net horses-power developed by the engine,	69·8090	115·2637	117·0824
	Total horses-power developed by the engine,	97·3647	143·0258	145·0219
ECONOMIC RESULTS.	Number of pounds of feed water consumed per hour per indicated horse-power,	28·3079	26·2093	25·6694
	Number of pounds of feed water consumed per hour per net horse-power,	33·0033	28·8035	28·1715
	Number of pounds of feed water consumed per hour per total horse power,	23·6629	23·2126	22·7441
	Number of Fahrenheit units of heat consumed per hour per indicated horse-power,	31979·2535	29518·5124	28916·7922
	Number of Fahrenheit units of heat consumed per hour per net horse-power,	37285·6168	32440·2587	31735·4286
	Number of Fahrenheit units of heat consumed per hour per total horse-power,	26731·8267	26143·4461	25621·4174

STEAM JACKETING.

By Chief Engineer ISHERWOOD, U. S. Navy.

DE AT MULHOUSE, IN ALSACE, GERMANY, ON THE JACKETED CORLISS CONDENSIN
TO WEIGHT OF STEAM CONSUMED UNDER THE DIFFERENT CONDITIONS OF NO STEAM
AND PARTLY FILLED WITH ITS WATER OF CONDENSATION, BUT NO STEAM IN THE PIS
AM IN THE PISTON; AND, FINALLY, OF THE CYLINDER JACKETS AND PISTON FILLED
ly constant, but the steam was used with different measures of expansion. The throttle valve

	No steam in the steam jackets of the cylinder, nor in the steam-piston.			Steam jackets of the cylinder not thoroughly drained, but filled partly with boiler steam and partly with its water of condensation. No steam in the steam-piston.	Boiler s of the the st
	A	*B*	*C*	*D*	
. . .	May 6th, A.M.	April 8th.	April 9th.	April 10th.	May
. . .	5·6814	10·7080	5·6772	10·6625	
	13089·5382	35550·5679	18725·6027	34813·0193	101
n the steam jackets of . . .	.....	.....	.....	1387·0796	5
the steam-piston, .	.....	.....	.....	.....	.....
from the steam jackets . . .	.....	.....	.....	.....	.....
n the steam jackets of . . .	.....	.....	.....	3·9844	
the steam-piston, .	.....	.....	.....	.....	.....
ondensed in the steam . . .	.....	.....	.....	.....	.....
. . .	17019·	31605·	16762·	31969·	153
mosphere, .	67·7148	66·2072	67·1601	67·7000	
inch above the atmos- . . .	64·1022	62·7072	63·6600	63·2900	
. . .	Wide.	Wide.	Wide.	Wide.	Wi
off, . .	0·0580	0·1050	0·1050	0·1550	
. . .	12·3978	7·9033	7·9033	5·7037	
. . .	1·9907	2·0680	2·0880	2·1648	
. . .	80·	83·	83·	84·	
er, . .	2303·9283	3320·0007	3298·3870	3264·9959	19
. . .	49·9261	49·1922	49·2085	49·9711	
ounds per square inch . . .	71·9630	70·5680	71·5210	71·1510	
per square inch above . . .	2·9860	3·1020	3·1320	3·2472	
per square inch, .	15·2113	24·0281	24·3657	29·3373	
uare inch, .	13·0472	21·8640	22·2016	27·1732	
quare inch, . .	18·1973	27·1301	27·4977	32·5845	
. . .	81·3881	126·6726	128·4950	157·0947	1
. . .	69·8090	115·2637	117·0824	145·5213	
. . .	97·3647	143·0258	145·0219	174·2606	1
ted horse-power, .	28·3079	26·2093	25·6694	20·7836	
rse-power, .	33·0033	28·8035	28·1715	22·4365	
orse power, . .	23·6629	23·2126	22·7441	18·7363	
licated horse-power,	31979·2535	29518·5124	28916·7922	23395·7265	224
horse-power, .	37285·6168	32440·2587	31735·4286	25256·3664	255
al horse-power, .	26731·8267	26143·4461	25621·4174	21091·1175	194

CONDENSING STEAM ENGINE DRIVING THE FACTORY OF MESSRS. SCHLUMBERGER, SON & CO., TO
NO STEAM IN THE CYLINDER JACKETS NOR IN THE PISTON; OF THE CYLINDER JACKETS
N THE PISTON; OF THE CYLINDER JACKETS FILLED WITH STEAM OF BOILER
N FILLED WITH STEAM OF BOILER PRESSURE.
rottle valve was wide open throughout, and the steam used was saturated.

the hor- ned, rtly eam h its den- the	Boiler steam in the steam jackets of the cylinder, but no steam in the steam-piston.		Boiler steam in the steam jackets of the cylinder, and in the steam-piston.					
	E	*F*	*G*	*H*	*I*	*J*	*K*	*L*
	May 6th, P.M.	April 11th.	May 7th.	May 8th.	May 11th.	May 10th.	May 9th.	April 12th.
	5·0708	10·7583	10·8740	10·5940	9·3958	10·9080	10·8000	10·7334
	10114·8081	34000·8426	21804·5669	27601·4743	28342·0635	32855·5257	33087·7010	35284·5109
	512·2794	1423·4869	1116·9229	1324·5963	1173·6358	1327·3678	1304·9939	1275·7276
.....	....	.....	292·5492	338·2278	351·1921	349·8886	370·2830	349·1283
.....	....	.....	1409·4721	1662·8241	1524·8279	1677·2564	1675·2769	1624·8559
	5·0647	4·1866	5·1224	4·7990	4·1410	4·0400	3·9440	3·6155
.....	....	.....	1·3417	1·2254	1·2391	1·0646	1·1171	0·9895
.....	....	.....	6·4641	6·0244	5·3801	5·1046	5·0611	4·6050
	15324·	32253·	32882·	32480·	28847·	32358·	31978·	32333·
	68·1557	66·8472	67·8854	67·1316	70·7584	70·7000	71·3558	67·3592
	64·7422	63·4195	64·5900	63·3484	67·9992	67·2027	67·7574	63·5475
	Wide.	Wide.	Wide.	Wide.	Wide.	Wide.	Wide.	Wide.
	0·0700	0·1550	0 0700	0·1050	0·1250	0·1350	0·1500	0·1550
	10·8259	5·7037	10·8259	7·9033	6·8471	6·4182	5·8670	5·7037
	1·9718	2·1648	1·9718	2·1069	2·1260	2·1260	2·1648	2·1844
	79·	84·	79·	82·	83·	84·	85·	85·
	1994·7164	3160·4289	2005·2020	2605·3874	2923·1279	3012·0577	3063·6760	3287·3564
	50·3668	49·9661	50·3985	51·0981	49·5868	49·4408	49·3488	50·2062
	72·6030	71·2800	72·4510	71·2090	75·8600	75·0640	75·6180	71·4080
	2·9577	3·2472	2·9577	3·1599	3·1890	3·1890	3·2472	3·2766
	18·5252	29·5856	19·1925	24·5181	27·8458	28·7398	29·5327	29·9900
	16·3611	27·4215	17·0284	22·3540	25·6817	26·5757	27·3686	27·8259
	21·4829	32·8328	22·1502	27·6780	31·0348	31·9288	32·7799	33·2666
	100·3357	158·4246	103·6611	134·2635	147·9764	152·2772	156·1874	161·3620
	88·3128	146·8363	91·9725	122·4127	136·4761	140·8108	144·7423	149·7180
	115·9589	175·8127	119·3660	151·5674	164·9232	169·1740	173·3606	178·9918
	19·8804	19·9491	19·3438	19·4050	19·7540	19·7801	19·6154	20·3725
	22·5869	21·5235	21·8022	21·2836	21·4186	21·3908	21·1664	21·9570
	17·2019	17·9761	16·8030	17·1896	17·7242	17·8045	17·6723	18·3659
	22481·7424	22451·2258	21873·0947	21879·1860	22310·6595	22280·4747	22078·5215	22910·1149
	25542·3868	24223·0957	24652·9423	23997·3122	24190·7002	24094·7811	23824·2818	24691·9815
	19452·7617	20230·7613	19000·0729	19381·3170	20018·1528	20055·1419	19891·4248	20653·5712

REPAIRING A BROKEN CRANK WITH WIRE ROPE.

The following description of the temporary repairs made to the broken cranks of the U. S. steamer *Pensacola* by G. W. Stivers, Passed Assistant Engineer U. S. Navy, is interesting in showing what may be done with wire rope in the way of repairs on shipboard.

The after crank of the forward engine only is shown, this one having been broken entirely across; but the plan adopted in banding both cranks of the after engine, which were broken nearly across, was precisely the same. The crank shaft and cranks were in one solid forging, and the fractures were directly across the bodies of the cranks, between the crank pins and the shaft, as if following the plane of contact of the fagots used in building up the cranks in the smithery.

For several months the existence of a very slight crack in the after crank of the forward engine was known, but frequent examinations failed to show any extension, and it was considered simply a surface flaw of no great consequence.

At about 5 P.M., June 18th, 1880, the ship being on her way from San Francisco to Puget Sound, it was found that this crack was rapidly extending. The weather was fine, sea smooth, and with square sails set the engines were slowed down, while preparations were made to strengthen the crank by temporary bands, so as to reach Victoria, where it was expected that a heavy band could be forged and shrunk on. The only iron that could be worked on board ship was a piece $3\frac{5}{8}$ inches wide and $\frac{3}{4}$ inch thick, and it was proposed to make of this two bands, to embrace the crank side by side and to be set up by two 1-inch bolts on each side, passing through lugs formed by bending up and thickening the ends. The strength of the bands as straps was therefore only that of two 1-inch bolts, and its utter insufficiency was evident.

At about 9 o'clock that night the crank had broken entirely across, but as the two parts moved together as usual, the irregular surfaces of the break and the long forward journal preventing their separation, the engines were kept slowly revolving until noon of the next day, when the plan of iron bands was abandoned, before being carried out, in favor of the following one, proposed by Mr. Stivers.

Ten gutter pieces or shoes were made of an old iron grating and placed equidistant about the crank in order to keep the bottom turns of wire rope from spreading apart when the riding turns came to be put on over them. The shoe at the extreme end and that on the butt of the crank only were secured in place by a small bolt through the centre, the other shoes being held in proper position by hand until bound by the first turn or two of rope. Into the hub of the crank a bolt one inch in diameter was tapped, to which the end of the rope was secured, and the work of wrapping the crank consisted simply in passing the wire rope continuously around the crank, hauling each turn taut by means of a heavy deck tackle passing down through the engine room hatch, and seizing each turn securely to the one immedsately preceding it before slacking off the tackle. It was estimated that a tightening pull of about two tons was brought on each turn of rope, and the seizing of the separate turns having been done very expertly there was no slacking back of the wire rope during the progress of the whole work.

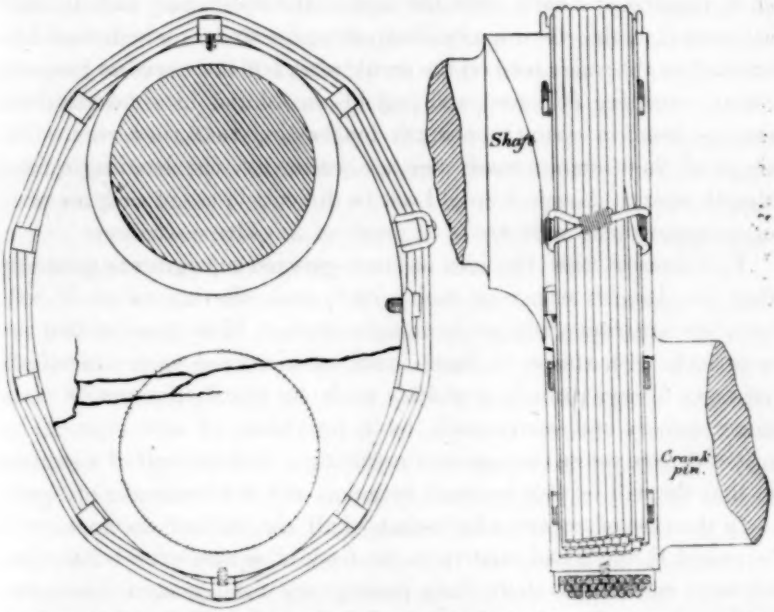
In this manner eleven turns of the rope were put around the crank side by side, just filling up the space between the jaws of the shoes; then over these were put ten riding turns, and over these again nine riding turns, making altogether thirty turns of wire rope encircling the crank. The finishing end was simply passed around the banding at one of the shoes and stopped, as shown in the sketch.

The wire rope used in this work was of $\frac{9}{16}$ inch diameter, consisting of five strands of 17 wires each, arranged about a central hemp core of $\frac{3}{16}$ inch diameter, the wires being of number 19 wire gauge.

The work of banding this crank was completed in seven hours, and just as it was finished it was found that both the cranks of the after engine were broken nearly across, the cracks extending entirely through each crank to within about one inch of each side, in about the same direction and relative position as in the forward crank. This discovery caused the abandonment of the attempt to reach Victoria; the ship was headed to the southward, with the intention of returning as best we could to San Francisco under sail, and, the banding of the forward crank having been so satisfactorily accomplished, it was decided to strengthen the after cranks in the same manner, so that the engines might be used in case of emergency.

This was done, and when about 200 miles from San Francisco, the wind blowing lightly from ahead and sails being useless, the engines

were started and worked continuously without stopping for over 45 hours, until the anchor was dropped in the harbor of San Francisco. During this time 45,835 revolutions were made, an average of 16·85 revolutions per minute, and an average speed made of 4·41 knots per hour under steam alone. The next day the ship was steamed up to the Mare Island Navy Yard, 26 miles from San Francisco, the engines being stopped and started seventeen times during the run to allow target practice, and upon arrival at the yard the rope banding was found to be as firm and unyielding as when first put on the cranks.



Arrangement of Wire Rope Banding, as applied to the fractured cranks of the U. S. S. *Pensacola*. Designed by GEO. W. STIVERS, Passed Assistant Engineer U.S.N.

The speed at which the engines were run with these fractured cranks was low, for the weather was fine and no necessity required the taking of the least risk; the initial pressure above zero on the pistons was 20 pounds, cutting off at 9 inches, there being two cylinders 60 inches diameter and 36 inches stroke; yet it is evident from a calculation of the strength of the banding on the extreme after crank, which transmits the power of both engines, and which would have been further strengthened if more wire rope had been at hand, that a considerably greater speed could have been safely attained.

The gutter pieces or shoes were, it will be seen, indispensable to the successful application of the wire rope banding, for they prevented the first course of rope from spreading under the pressure of the riding turns; they allowed the driving of iron wedges beneath them without injury to the rope, in case it should become slack and require tightening, and they permitted the passing of the end of the rope between the crank and the whole banding so as to secure it firmly.

It was expected that the wire rope would in a short time stretch, and the intention was therefore to first drive iron wedges under each shoe, nipping the ends over the end of the crank, and then to drive all around, under the rope banding, dry pine wedges which would be swelled by the water used on the crank pins, but there was no necessity for any wedging whatever, and perhaps would not have been had the engines been in operation a much longer time than they were. The shape of these cranks made the application of the banding quite a simple matter, though it would not be difficult to adopt such a system of wrapping with wire rope to a crank of any shape whatever.

It is thought that the idea has not occurred to engineers generally that they have in wire rope such a ready and effective means of temporarily repairing damages to engines at sea. Many repairs that are now made with straps or bands hastily constructed under the disadvantages always attending smith's work on board ship can be much more quickly and easily made by a few turns of wire rope. This material may yet be the means of repairing a broken shaft of a steamer so that she will be able to steam into port at a moderate rate of speed.

In the case of repairs to a broken shaft the ends of the rope could be passed through and secured to the back of square pieces fitted into keyways cut in the shaft, then passing the rope around the broken shaft and securing the other end of the rope in a like manner; these pieces to be bolted to the shaft with tap bolts; for backing the rope must be wound around the shaft in the opposite direction.

The ease and facility with which repairs can be made with wire rope commend it to engineers and steamship owners as a part of the necessary outfit for a steamship. J. C. KAFER.

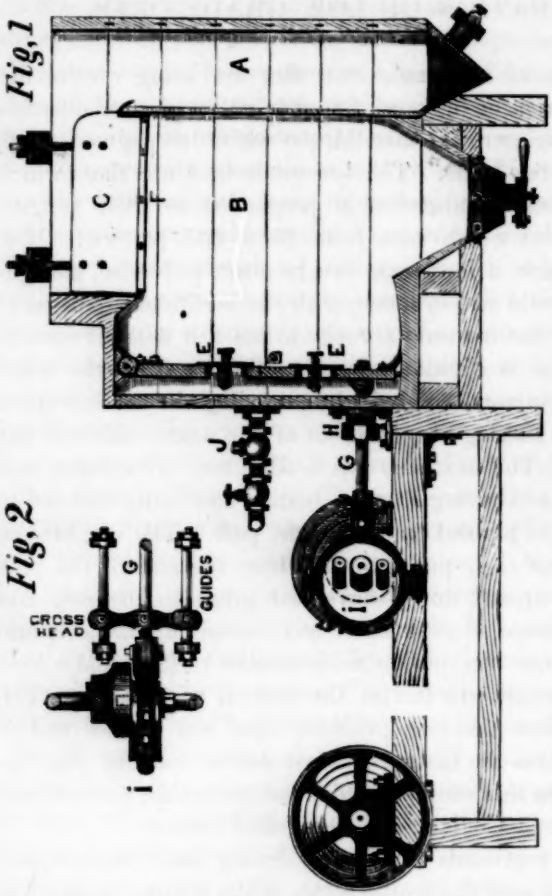
Magic Well.—An artesian well at Atchison, Kansas, furnishes both fresh and salt water. A long tube, which reaches to the bottom of the well, penetrates a salt vein, while a shorter one only extends to a stream of fresh water.—*Fortsch. der Zeit.* C.

CONCENTRATION OF LOW GRADE ORES.

The large deposits of low grade ores that are being continually uncovered in the search for the ores of higher grade place a question before the mining engineer and metallurgist which has claimed much attention in the past few years. The low grade ores are those which run very low in metallic substance in proportion to their gangue. That is a low grade ore which runs from $5 to $35 per ton. If it were necessary to work a low grade ore, to roast, pulverize, amalgamate and retort it would cost so much, with the additional expense of mining and hauling that it would not pay to touch it without concentration; concentration is dividing the metallic ore from the waste rock. This is done in some countries by pounding the ore into small pieces and, by hand, picking the good out of the waste; this was the original separation. The next step was to fill a tank with water, suspend a smaller box in it having a screen bottom and being fastened to a long pole, which was pivoted on an upright post. The ore, broken into small pieces, was then put into this box, the end of the pole grasped and a quick up and down movement given to the pole and box. This quick plunge of the smaller box, containing the ore, into the water in the large box pushes the quartz or rock up and allows the metal, being heaviest, to settle at the bottom of the box. The rock, being lighter than the metal, collects upon the surface and is skimmed off. This was the first mechanical means used for the separation of ore. From this simple machine has grown the present concentrator, now in use in England and the United States.

The following cut represents the Rogers Swing Gate Concentrator, designed especially to meet the requirements of the mining engineer in working the low grade ores successfully and profitably. As the concentration of ore depends upon the pulsation of water in the gig box, where the ore is separated from its gangue, light ores require but little agitation and heavy ores greater agitation. This has long been known as a great point in concentration, but there has never been a machine constructed with this principle in view, so that any ore, either of great or light specific gravity, could be treated until the present one, represented in the cut. This is the only concentrator which is capable of treating *all ores.* It is recommended on account of its cheapness,

simplicity and capability of working any ore which will separate from its gangue.



These machines consist of a water tank divided into two compartments, A and B; one for waste, A; and one for concentration, B. In the main compartment is suspended the box C by four bolts, passing through brackets; these bolts are for the purpose of leveling the screen F and for altering its height, in order to get more or less bed. In the main compartment, B, is suspended the vibrating gate D, provided with valves E E. These valves are opened and closed by the variation in the pressure of the body of water on either side of them. This pressure of the water is rendered intermittent by the backward and forward swing of the gate to which they are affixed. The forward swing of the gate moves the large body of water in advance of it upward through the meshes of the screen, while at the same time a partial vacuum is produced in the smaller body of water behind the gate. The check valve J, connected with a suitable reservoir of water, then opens and supplies this deficiency. The vibratory motion or swing of the gate is obtained by means of a rod, G, attached to the lower part of the gate, passing through the stuffing-box H and moved by the adjustable eccentric I.

In cases where water is scarce these concentrators can have a pipe, protected with a screen nozzle, projecting into the waste compartment, A, and running into the main compartment, B, where a check valve allows of an intermittent stream being pumped, by the action of the vibrating gate, through from the waste and forcing it up through the screen. By this simple arrangement the water can be used over and over again.

It will be seen at a glance that this concentrator is so perfectly adjustable in all its working parts as to allow of its being run by

unskilled labor. Another great desideratum is its capability to treat ores of greater or less specific gravity merely by altering vibration of the gate, by means of the adjustable eccentric, thereby producing either a slight or heavy pulsation of water through the screen. Any desired speed can be obtained by means of the cones. The tight and loose pulleys admit of instant stoppage, without interfering with any of the pulleys or shafting in the mill. Extra castings for the screen grates are provided with each machine, so that different sized screens, from 4 to 80 mesh, can be placed in position in a few minutes, causing very little delay in the work. The weight of each machine, tank included, is about 850 pounds, and each machine can be shipped in sections, and put together at the mines from the construction drawings.

Six of these concentrators are already in successful operation at Alpine, Colorado, by the Pembina Mining and Milling Company, where low grade ores are being worked with the best results possible.

APPROXIMATE QUADRATURES OF THE CIRCLE. IV.

By PLINY EARLE CHASE, LL.D.

A note from E. Dietze, C.E., calls attention to the following formula, which he thinks was published in the *Leipziger Illustrirte Zeitung* in the fall of 1856.

$$\pi = \tfrac{1}{4}\sqrt{5} + \sqrt{21} - 2.$$

The formula may be easily constructed, for

$$2r\pi = \sqrt{r^2 + \left(\frac{r}{2}\right)^2} + 2\left[\sqrt{(5r)^2 - (2r)^2} - 2r\right]$$

It gives $\pi = 3{\cdot}1415926893$, the true value being

$$\begin{array}{ll} & 3{\cdot}1415926539 \\ \text{Error,} & \cdot 0000000354 \end{array}$$

This error is only $\frac{2}{15}$ as great as in the sixth approximation of my note.* The construction is much easier and simpler than that of Perkins, but it is more difficult than either of my own.

* This Journal, June, 1880, p. 409.

Frozen Dynamite.—Captain George Lebon recommends the use of an increased quantity of fulminate in dynamite cartridges, so that they can be readily exploded when frozen, thus obviating the necessity and consequent danger of melting them in cold weather. He mentions numerous experiments, at temperatures of twenty degrees below zero (—4°F.), in which charges were exploded without difficulty or failure.—*Ann. des Ponts et Chauss.* C.

Wormwood as an Insectifuge.—M. Poyrot having observed that the immense tracts of wormwood, upon the American plains, are free from insects of every description, is experimenting with the plant as a preventive of phylloxera. He finds no difficulty in cultivating the wormwood, and he proposes to mix the stalks with manure, or simply bury them in the ground in the neighborhood of the vines. His suggestions have been sent to the phylloxera committee of the French Academy.—*Comptes Rendus.* C.

Aluminium as a Voltaic Element.—Aluminium, like iron, has the remarkable peculiarity, when immersed in concentrated nitric acid and then placed in contact with ordinary aluminium, of exciting a galvanic current. It is thus possible to construct a battery from a few elements of aluminium alone, sufficient to decompose water and to bring a thin platinum wire to a brilliant glow. The aluminium in this arrangement is of course dissolved. It could, perhaps, be recovered by the means of zinc.—*Liebig's Annalen.* C.

Preservation of India Rubber under Water.—Great losses are often experienced by the users of india rubber tubing, on account of the brittleness which it often acquires in use. A writer in *Dingler's Journal* gives an encouraging account of his success in remedying the difficulty by laying the pipes in water which is often renewed. Even the thickest and stiffest tubes remain soft and pliable, without any perceptible diminution of elasticity, and he has been unable to discover any trace of injurious change. For some uses he soaks the pipes in melted paraffine. When they are kept in water they undergo great changes of color, and upon cut surfaces they often appear greasy and bleached, but all the changes seem beneficial rather than otherwise. Thin rubber bands, however, often become so brittle that they can be easily rubbed into small pieces by the fingers.—*Dingler's Journal.* C.

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Hardening Stone.—Dr. Gehring, of Landshut, Bavaria, has invented an enameling liquid which is said to render ordinary stones and cements harder than granite and to facilitate the imitation of marbles and other valuable minerals. When applied to metals he claims that it will be found an excellent preservative against rust.—*Les Mondes.* C.

Regulator of Vapor Pressure.—M. D'Arsonval describes an instrument which he has tested by daily use for more than three years, and which accomplishes the following purposes: 1. To maintain the pressure of any given vapor constant in a boiler whatever may be the supply. 2. To use fuel only in proportion to the quantity of vapor required. 3. To make the action of the instrument completely automatic and without danger of explosion.—*Comptes Rendus.* C.

Improved Electric Batteries.—Azapis has modified the Bunsen cell, using a solution of cyanide of potassium, caustic potash, chloride of sodium or sal ammoniac, instead of dilute sulphuric acid, thus reducing the consumption of zinc and effecting greater constancy of current. Woehler places a roll of sheet aluminum in a round glass vessel containing very dilute hydrochloric acid or dilute caustic soda. Within this larger roll is placed a porous cell, containing concentrated nitric acid, and a smaller roll of aluminum. Each roll has a lug or projection, which is inserted into a circular cover of ebonite and thus kept in place.—*L'Ingen. Univ.* C.

Electric Radiometer.—Bertin has repeated before the French Physical Society the first series of his experiments upon the electric radiometer. When the pressure of the air in the radiometer reaches 130 mm. (5·12 in.) the rotation begins, but it is uncertain; at 90 mm. (3·54 in.) it is decided, but its direction is always determined by some defect of symmetry in the apparatus. At 30 mm. (1·18 in.) it ceases, but may be produced by a spark or warming one of the tubes; it acts as if a wind blew from the cold to the warm pole. At 15 mm. (·59 in.) the electric rotation occurs alone, and is positive, as if the wind came from the positive pole. At 10 mm. (·39 in.) there is no rotation. From 5 mm. to 2 mm. (·197 to ·079 in.) the rotation is negative. From 2 mm. to ·2 there is no rotation. At 1 mm. (·004 in.) and less the rotation is always negative, the negative tube being fluorescent.—*Chron. Industr.*

New Roof.—It is thought that the new roof on the cupola of St. Peter's Cathedral, in Rome, will be finished in two years. It was begun seventeen years ago. The roof is divided into sixteen sections, each of which requires one million pounds of lead.—*L'Ingen. Univ.* C.

Dependence of Electric Conductivity in Coal upon Temperature.—J. Borgmann claims some priority in investigations of the electric conductivity of coal, and reports a series of experiments by which an increase of conductivity at increased temperature was shown in every instance. He found, also, that the light rays produced a greater effect than the dark rays.—*Ann. der Phys. und Chim.* C.

Poteline.—M. Potel has communicated to the French Société d'Encouragement a compound which may be employed in hermetically sealing bottles and flasks, or in making an artificial marble for the ready manufacture of various useful and ornamental articles. It is composed of gelatine, glycerine and tannin; sulphate of baryta or zinc white may be added to make it opaque, and it may be dyed of any desirable tint by means of ordinary vegetable colors.—*Chron. Industr.* C.

Remedy for London Smoke.—W. D. Scott-Moncrieff proposes to extract one-third of the gas from the coal before it is used in London fires. This would require that three times the quantity should be passed through the retorts, but the advantages would be very great. The companies would double the quantity of by-product, in the shape of tar and ammoniacal liquids; the community would have 24-candle gas instead of 16-candle gas; the fuel resulting from the process would light readily, and it would make a cheerful fire, giving out 20 per cent. more heat than common coal; and London would become a smokeless city. The smokeless fuel, which results from an extraction of 3333 cubic feet of gas per ton, has a heating capacity fully 20 per cent. greater than common coal, and 10 per cent. greater than coke. He calculates that there will be an annual balance in favor of his scheme of £2,125,000. This may be taken as the yearly value of London smoke, which is now wasted, but which he proposes to convert into useful products by the plant that is now in use.—*L'Ingen. Univ.* C.

Satellite Geology.—In presenting the Annual of the Bureau of Longitudes, M. Faye described, as usual, the improvements which have been introduced into the volume. The one which will probably attract the most general attention for its novelty is a notice by M. Faye himself upon the comparative geology of the Moon and the Earth, with illustrative plates.—*Comptes Rendus.* C.

American Vines in Europe.—In a report upon Vimont's memoir on the phylloxera, M. Zundel speaks highly of the success which has attended the introduction of American vines. The effectual resistance of certain varieties to insect attacks has been thoroughly established when they are placed in suitable soils. Some of the vines produce good wines, of fine color and rich in alcohol from their own native fruit. The French varieties, such as the Aramon and Chasselas, yield abundantly when grafted upon American stocks, and the quality of the grape is not injured in any way by the grafting.—*Bull. de la Soc. de Mulhouse.* C.

Electric Expansion.—G. Quincke gives a summary of the observations which have been made upon the expansion of Leyden jars and other glass vessels, under the influence of electricity, from the days of Fontana to the present time. He has communicated to the Berlin Academy the results of some of his own investigations, in which he considers the various influences of positive and negative electricity, the resistance of the discharger, the intensity of the electric current in the glass, the thickness and condition of the wall of the thermometer bulb, the fluid in the thermometer, the elasticity of the glass, and various other modifying circumstances.—*Wiedemann's Annalen.* C.

Zincography.—M. Thonrocq, a Paris lithographer, has been very successful in substituting zinc for lithographic stones. By using 5000 zinc matrices, worth 38,500 francs ($7700), he has avoided an expenditure of 250,000 francs ($50,000) for stones, besides considerable saving in the cost of handling and manipulating. He has published in this way more than 350,000 copies for some of the leading French editors, the Polytechnic School, the Department of Bridges and Highways, the Ministry of Public Works and different municipalities. Each plate is good for 40,000 impressions, and the change seems desirable in all cases where large editions are to be worked off within a brief period.—*Bull. de la Soc. d'Encour.* C.

Brest Diving-Bell.—H. Hersent describes a diving-bell which was employed by himself and M. Castor for removing the rocks in the harbor of Brest. The rocks were hard and massive, consisting of schists mixed with quartz, granite, etc., and the work was accomplished safely, rapidly and with great economy. The bell is so arranged as to be easily used for all kinds of submarine work.—*Mem. de la Soc. des Ingen. Civ.* C.

Smoke and Steam under the Microscope.—L. J. Bodaszewsky calls attention to the rapid oscillatory movements which are disclosed by the microscope in the smoke of burning paper, wood, cigars, etc., when concentrated sun or electric light is thrown upon them through a lens. The particles are of a spherical form, and they are continually darting against each other, so as to represent very strikingly the motion of gas molecules according to the kinetic theory. Similar movements are observed in the vapors of nitric, sulphuric and phosphoric acids, sulphur, ammonia, etc., when examined under the microscope by the light of a glowing platinum wire.—*Dingler's Journal.* C.

Removal of a Furnace "Bear."—A furnace near Vienna, which has been out of blast for four years, was obstructed by "bear," or "sow," that is, a mass of slag and iron, which resisted all attempts at removal by breaking or wedging. The mass consisted of two cylinders, the lower one from 16 in. to 80 in. high and 13 ft. 4 in. in diameter, and the upper one between 8 ft. and 9 ft. in both dimensions. The latter was a mixture of slag and iron, while the former consisted of nearly pure metal. Six holes were bored in the junction of the cylinders to an average depth of 32 in. They were loaded with gelatine dynamite and fired by electricity. By using 27 charges, amounting in all to 7·7 lbs. of dynamite, the two masses were separated. To divide the lower mass, 19 bore holes were used, employing in all 89 charges and 20 lbs. of dynamite. The division of the larger fragments required 22 lbs. of dynamite, 32 detonators and four coils of safety fuse. About 67½ tons of good metal were recovered, at a total cost of £30. The shaking of the furnace masonry by the explosions was very slight, and no sensible damage was produced.—*L'Ingen. Univ.* C.

Vanadium Ink.—Berzelius found that by treating an infusion of galls by a solution of vanadate of ammonia, in place of sulphate of iron, he could produce an ink of remarkably good quality. At the time of his discovery, in 1831, it was of no practical interest, because the vanadates were very costly. At the present time their cost has been so much reduced that his recipe can be employed for ordinary inks, which have the additional advantage of presenting great resistance to most reagents and destructive materials. Gum arabic can be dispensed with, and the chance of moulding or alteration thus reduced. —*Chron. Industr.* C.

Absorption Spectrum of Ozone.—J. Chappuis has continued his experiments upon ozone, and finds that the absorption spectrum of oxygen, which has been ozonized by electricity, presents eleven obscure bands in the part of the spectrum which is ordinarily visible. One of the bands is in the orange, and corresponds with the telluric bands which Angström noticed and attributed to something else than water vapor. Two of the other bands of Angström appear also to be due to ozone. The relative stability of ozone at low temperature and low pressure, and its continual production by electric discharges, make it an important element in the upper regions of the atmosphere; its blue color must therefore undoubtedly play an important part in the coloration of the sky.—*Comptes Rendus.* C.

Variations of Luminous Sensibility.—A. Charpentier has experimented with a number of small diaphragms in order to cut off the light from his lanterns and produce images upon the retina having diameters varying between one-sixteenth of a millimetre and a millimetre ($\frac{1}{400}$ in. and ·039 in.). As long as the diameter of the object was superior to two millimetres and the image on the retina was greater than ·176 mm. (·007 in.) no change was noticed in the degree of light required; but below these limits he invariably found, for six different surfaces, that the intensity of light required varied inversely as the luminous surface, so that the product of light by surface was nearly constant. These experiments have already suggested to the investigator numerous interesting questions in regard to the comparative sensitiveness of different portions of the retina and the number of optical cones that are required in order to produce the sensation of light.—*Comptes Rendus.* C.

Length of Jupiter's Day.—The Emperor of Brazil has transmitted to the French Academy a note of M. Crul's upon the time of Jupiter's rotation. The sharpness of outline and the bright color of the brown spot which has been so long visible enabled him to deduce from nearly 1100 rotations a period of 9 h. 55 m. 36 s.—*Comptes Rendus.* C.

Optical Telegraphy.—A. Crova describes an apparatus for sending light signals, which he invented in conjunction with Le Verrier, in 1870, and which he regards as substantially identical with Mercadier's, the principal difference being that he used oil instead of petroleum. The signals were visible in broad daylight, and when the sky was somewhat clouded correspondence could be carried on by day as well as by night. He found it necessary to employ oxygen under a feeble pressure, and to have the manipulating key armed with a strong string, so that it could be suddenly opened and closed. Without this precaution the signal would overlap and produce confusion.—*Comptes Rendus.* C.

Book Notices.

A Physical Treatise on Electricity and Magnetism. By J. E. H. Gordon, B. A. Camb., Assistant Secretary of the British Association. 2 vols., 8vo. New York: D. Appleton & Co. 1880.

The object of the work, as stated by the author, is to give a complete account of certain portions of electrical science, viewed, almost entirely, from a physical rather than a mathematical standpoint. To carry out this idea no mathematical considerations have been introduced into the body of the text that require, on the part of the reader, a more extended knowledge than algebra as far as simple equations. In all cases where a thorough understanding of the subject requires the aid of higher mathematics, explanations are either entirely omitted, or are introduced as foot notes or appendices.

The work is divided into four parts. Part I, 141 pp., treats of Electro-Statics; Part II, 56 pp., of Magnetism; Part III, 323 pp., of Electro-Kinetics, and Part IV, the remainder of the work, of Electro-Optics.

In Part I we find, after the usual preliminary statements regarding

the properties of an electrified body, a short account of electrical machines, an explanation of electric force and potential, and a full description of electrometers, followed by the theory of absolute measurements. The balance of Part I, comprising about two-thirds of the whole, is devoted to the consideration of the determination of specific inductive capacity.

Part II discusses the properties of magnets; explains fully the action of terrestrial magnetism on the needle, treats of the variations of the needle; gives full descriptions of the most recent methods for terrestrial magnetic observations, and concludes with general observations on terrestrial magnetism.

Part III describes briefly the various forms of voltaic batteries; discusses the actions of currents on magnets and on other currents, and defines the electro-magnetic units It also gives full descriptions of the methods employed for measuring electric resistance; discusses electro-magnetism; barely mentions the telephone and Hughes' induction balance; gives a full account of the British Association unit of resistance, and concludes, in Vol. I, with descriptions of the induced currents caused by making and breaking the circuit.

In Vol. II, Part III discussses dia-magnetism; the induction coil and its discharge; the striæ observed in partial vacua. Very full descriptions are given of Spottiswoode and Moulton's researches on the sensitive state of discharges through rarified gases, together with a less extended description of Crooke's investigation of electrical discharges in high vacua. Electrolysis is alloted but eight pages, and a bare mention made of magneto-electric and electro-magnetic engines and the electric light. Part III then concludes with a discussion of thermo-electricity, electricity of contact and electro-magnetic units.

Part IV gives full descriptions of the influence of magnetism in rotating the plane of polarization of light, and discusses the relations between statical electricity and polarized light. The final chapter gives a description of Clerk Maxwell's electro-magnetic theory of light.

In some respects, the book forms a valuable contribution to electrical literature. This is especially the case with Chaps. VII and IX, Vol. I, which treat of electrometers. Here we find a fair compilation which gives an accurate description of the various patterns of electrometers as now made and used. These descriptions are terse and clear, and are illustrated by unusually fine wood cuts. The chapter on the

theory of absolute measurement is excellent, and cannot fail to be of great value to the general student. Specific inductive capacity is ably and fully discussed, and the description of galvanometers is excellent. Many of the topics discussed in Vol. II are well handled.

There is, however, an unfortunate absence of logical connection between many of the different parts of the book that unpleasantly suggest to the reader a want of completeness, a lack of unity of plan. It would seem as though much of the compiled part of the book had either been hurriedly thrown together, or thoughtlessly selected from materials within easy access; while in many cases the written portions appear to have been prepared inconsecutively. The author, too, has given undue prominence to certain topics, and suppressed others connected therewith, in an exceedingly arbitrary manner. As an instance, we find that while the comparatively unimportant subject of the sensitive state of discharges through rarefied gases is assigned some 24 pages, the exceedingly important subject of electric motors, dynamo-electric machines and electric lighting is summarily dismissed after but 9 pages.

It is to be regretted that, in so extended a work on electricity, the author's teachings should be so weak as to the nature of the electrical force. At the very outset of the work, in the first paragraph, we meet the mysterious statement that "We have no conception of electricity apart from the electrified body; we have no experience of its independent existence," a statement which, of course, is true of any phase of energy. Then again, on pages 14 and 15 we read, "For purposes of calculation electricity of either kind may be treated precisely as if it was a material incompressible fluid," and, "For purposes of calculation, any increase or decrease of electrification may be considered to be produced by the addition or by the taking away of a quantity of something (which we call electricity)." How much better it would be for the mind of the reader, which is assumed to be but little trained to mathematical conceptions, if the author stated plainly that the thing added or subtracted was energy. The absence of such a statement is all the more marked, since on page 24, Vol. I, we are given the value of the unit of electromotive force, the volt, in absolute units of potential; while in the closing paragraph of the book, page 276, Vol. II, we read as a conclusion drawn from a brief consideration of Maxwell's "Electro-Magnetic Theory of Light," as follows, viz.: "The

numerous direct relations which exist between light and electricity leave us but little doubt that they are very closely related, and that their effects are but two forms of that common energy whose nature is unknown, but which certainly underlies all physical phenomena."

The publishers are to be complimented on the excellent character of the numerous wood cuts. We regret that we cannot equally compliment them on the typography, since, throughout both volumes, wrong fonts and broken letters are of very common occurrence. E. J. H.

FOUR LECTURES ON ELECTROSTATIC INDUCTION. By J. E. H. Gordon, B.A., Assistant Secretary of the British Association. 8vo. New York: D. Van Nostrand. 1881.

These lectures were delivered at the Royal Institution of Great Britain, in January and February, 1879.

After explaining the general nature of induction, and pointing out the difference between it and conduction, the author discusses the general action of the Leyden jar, and gives a brief account of the theory of lateral pressure accompanying the state of strain produced by induction. The variations in the specific inductive capacities of different substances are then explained, and some account given of the earlier, as also of the more recent determinations of specific inductive capacity. The last lecture contains, among other subjects, a discussion of Clerk Maxwell's electro-magnetic theory of light.

The topical arrangement is good, and the subject matter is, on the whole, well handled, but the work shows either undue haste, or else a lack of judgment in the matter of expression. Instances of the latter occur in passages like the following, viz.: "The glass or sealing-wax, after being rubbed, is found to be in the state called '*electrification.*'" Also, "For every *bit* of positive electricity we produce an exactly equal quantity of negative."

The author leaves his reader in too much doubt as to the nature of electricity. Instead of regarding it, as is now almost universally done, as a phase of energy, and clearly pointing out how every other variety of energy can readily be converted into electric energy, we find such ambiguous teachings as these, viz.: "We do not know whether the properties of an electrified body are caused by one or two electric fluids entering or leaving it, as water into a sponge; or by a motion of

its molecules, as when a body is heated; or by a strain or twist of its structure, as when steel is magnetized." * * * "We have no experience of its independent existence."

Later in the book we find the following remarkable ideas advanced, viz.: "We cannot make or destroy electricity—" * * * "When we rubbed glass, we produced positive electricity on its surface. Was not that a creation of electricity? No; for an exactly equal quantity of negative electricity was produced in the rubber." Here the author is decidedly at fault; we can both make and destroy electricity; that is, we can convert every variety of energy into other forms of energy; and so also we can convert electrical energy into other forms of energy. The argument used by the author to prove his assertion, that electricity was not created, because an equal amount of opposite electricity was produced, leads us to infer that he has the fluid hypothesis in mind when using the illustration. His idea appears to be that nothing has been created; the positive and negative fluids existed previously; the mechanical action of rubbing has simply separated the two fluids; therefore there has been no creation, but merely a separation.

He also makes the following remarkable assertion, "If this were possible (the production of a single kind of electricity without the production of its opposite kind, which of course is impossible), we might actually increase the quantity of electricity in the world. Experiment shows us that we cannot do this." Here again the meaning is ambiguous. If electricity be a species or phase of energy, he is at fault, since nearly all the energy in the universe might be converted into electrical energy, in which case the quantity of electricity in the world would be largely increased. If, however, he regards electricity as a kind of matter, and here we see indications of a lingering belief in a fluid hypothesis, he is right: since of course we can neither increase nor decrease the quantity of matter in the universe. Does the author believe that electricity is a kind of matter? E. J. H.

A Text Book of Elementary Mechanics for the use of Colleges and Schools. By Edward S. Dana, Assistant Professor of Natural Philosophy in Yale College. 12mo. New York: John Wiley & Sons. 1881.

"For we have done those things which we ought not to have done,

and we have left undone those things which we ought to have done," applies to many things other than our moral transgressions.

Certainly, if an elementary mechanics should have any one virtue, that virtue should be clearness of conception and accuracy of expression.

Glancing through the book, on page 220 we find the following statement: "A toothed wheel is a circular disc provided with teeth on the circumference; such a wheel, turning on one axis, interlocks with a second, turning on another axis, and in this way the *force* applied at the first is communicated to the second. There may be a *mechanical advantage* with a corresponding loss of speed, or a gain of velocity and a consequent *mechanical disadvantage.*"

Would it not have been much clearer to have said the *work* applied at the first is communicated to the second there may be a *gain in force* with a corresponding loss of speed, or a gain in velocity and a consequent *loss in force.*

"A mechanical advantage" may be gained from a given quantity of work in either direction; that is, you may gain greater speed or greater force at will, and a loss in force may prove anything but a mechanical disadvantage in many cases.

The use of the word "power" (see page 222) in the sense of force is also confusing. The power of a machine is the number of foot-pounds of work it will do in the unit of time taken. Prof. Dana is not alone in this erroneous use of language, but takes this word from others, who make far greater pretensions as mechanicians than he does in his modest preface.

Although we have four chapters on dynamics or kinetics, it is impossible to find in them any reference to the moment of inertia, or to the radius of gyration. There is the trouble with many af our elementary mechanics: the students read them, and it is true, too, that the great majority forget what they have read as rapidly as possible afterward; but they have also gained the false impression that they at least know the names of the fundamental conceptions of mechanics.

All who have in after life been obliged to work beyond the elements of any science know how very hard it is to get rid of youthful impressions and modes of thinking; it is, like speech, almost an incorrigible fault if acquired from an incorrect model.

Quoting from the preface, "The study of elementary mechanics is one of very great value in a course of liberal education;" but it had a great deal better be left out altogether than be wrongly taught.

In many cases it can at once be perceived that the writer has used a work on elementary mechanics as a thread on which to string hundreds of ingenious and elegant but *utterly useless* mathematical problems —useless to the mechanic we mean, not to the mathematician.

The amount of mathematics which can be used in an elementary mechanics, adapted to the capacity of the average collegian, is extremely small, and they must, too, be of the simplest kind. Why do not our writers endeavor to give, in intelligible language, a clear conception of what the fundamental ideas of mechanics are? Those who take an interest in the study will naturally have more than the average of mathematical acquirements in after life, and will be in a position to start from clearly defined ideas and thoroughly understood premises.

We are told that "momentum is equal to the product of the mass and velocity," and, in other words, that "the moment of inertia is equal to the mass multiplied by the square of the radius of gyration." What more do these statements convey to the mind of the student than the statement that two times two is four? Why not say that the momentum is equivalent to that constant force which, acting for one second, will bring the moving body to rest, and that the moment of inertia is equivalent to the statical moment of the sum of the momentums of all the particles of a revolving body? We then have at least some grasp of the subject.

We regret also to see that the part devoted to machines has been divided up into seven parts, each devoted to one of the so-called elementary machines. The lever, the cord and the inclined plane would have been all sufficient and covered every case. For instance, the screw is but a modification of the inclined plane, and although six pages are devoted to its consideration, we are nowhere informed of what is known to every machinist, that square-threaded screws must be used when the screw is intended to impart motion to its nut, and that V-threaded screws are used for the purpose of clamping two bodies together.

The reviewer does not wish to give the impression that Prof. Dana's little work is any more in error than the books from which he has compiled his manual, but has seized this opportunity to enter a protest against the writing of works which mislead by inaccurate language and by causing the student to believe that he has at least had a glimpse of the whole field of mechanics. W. D. M.

INTERMEDIATE LESSONS IN NATURAL PHILOSOPHY. By Edwin J. Houston, A.M., Professor of Physical Geography and Natural Philosophy, Central High School of Philadelphia, etc. 12mo. Philadelphia: Eldredge & Brother. 1881.

This volume is the latest addition to the very useful series of this author's school books. As announced in the preface, it is intended to fill the gap between his "Easy Lessons in Natural Philosophy" and his "Elements of Natural Philosophy." Prof. Houston's long experience as a teacher stands him in good stead as an author. He has no difficulty in placing himself *en rapport* with his pupils. He appreciates their difficulties and anticipates them. The work here noticed is characterized by the same clearness of explonations that we have had occasion to praise in noticing the author's earlier volumes; but while the text of his book is lucid and adapted for the comprenension of partly advanced students, it is at the same time strictly accurate.

The book is liberally illustrated, many of the engravings being new to works of this grade; some of them have been specially prepared for the work, while others are exceltent reproductions from more elaborate French and German works. By lending attractiveness to the subject they add materially to the educational value of the book.

The publishers have issued the work in very creditable style; it is well printed and substantially bound, and has the look of serviceability that a school book should have. W. H. W.

Franklin Institute.

HALL OF THE INSTITUTE, April 20th, 1881.

The stated meeting was called to order at 8 o'clock P.M., the President, Mr. William P. Tatham, in the chair.

There were present 129 members and 43 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced, that at their last meeting 15 persons were elected members of the Institute; he also read a preamble and resolutions with regard to the creation of a Trust for a Building Fund for the Institute, offered by the Committee on Stocks and Finance, and adopted by the Board of Managers at their meeting on April 13th, 1881.

Mr. William Sellers, Mr. Frederick Fraley and Mr. J. Vaughan Merrick were appointed the Trustees by the Board.

The Secretary reported the following donations to the Library:

Journal Franklin Institute. 112 numbers. 1870 to 1881.
From J. E. Mitchell.

Text-Book of Elementary Mechanics. By E. S. Dana.
From John Wiley & Sons, Publishers, New York.

American Sanitary Engineering. By E. S. Philbrick.
From Publisher of *Sanitary Engineer*, New York.

Illustrated Catalogue of Locomotives.
From J. B. Lippincott & Co., Publishers.

Forty-seventh Annual Report of the Royal Cornwall Polytechnic Society. Falmouth. 1879. From the Society.

Aeneidea, or Critical Remarks, etc., on the Aeneis. By Jas. Henry. Vol. 2. Dublin. 1879.

Memoirs of the Geological Survey of India. Vol. 15, Part 2; Vol. 17, Parts 1 and 2 and Record.

Palæontologia Indica. Ser. X, Parts 1 and 2, Vol. 1; Ser. XIII, Parts 1 and 2. Salt Range. From the Geological Survey Office.

Revista Cientifica Mexicana. Vol. 1, Nos. 10 to 12. 1880.
From the Publisher.

Transactions of the Royal Irish Academy. I. M. Series. Vol. 1. Science Series, Vol. 26; "Cunningham Memoirs." No. 1 and Proceedings. From the Society.

Annual Report of the State Geologist of New Jersey for 1880.
From G. H. Cook, S. G.

Early Society in Southern Illinois. By R. W. Patterson. And History of the Chicago Historical Society. From the Society.

The New Improved Bed of the Danube at Vienna. By Sir G. Wex. Washington. 1881.

Index to the Library of the American Society of Civil Engineers. Part 1, Railroads. From the Society.

Memoir of J. A. Meigs, M.D. By L. Turnbull, M.D. Philadelphia. 1881. From the Author.

Endowment of Scientific Research. By G. Davidson.

Variable Stars of Short Period. By E. C. Pickering. Cambridge. 1881. From the Author.

Opinion delivered by Mr. Justice Bradley in the case of R. A. Tilghman *vs.* Wm. Proctor. From Geo. Harding.

Meteorological Researches for the use of the Coast Pilot. Part 2. On Cyclones. From the U.S. C. & G. Survey.

Milling World and Chronicle of the Grain and Flour Trade. Buffalo, N. Y. From the Publisher.

Nouvelles Annales de la Construction. 1861—1863; 1865—1868; 1870—1874; and 29 unbound pamphlets. Also, Catalogue of Centennial Exhibition. 1876. From Lewis S. Ware.

Second Annual Report of the Indiana Bureau of Statistics and Geology. 1880. From the Bureau.

Annual Report of the Board of Regents of the Smithsonian Institution for 1879. From the Institution.

Alphabetical Lists of Patentees, etc. July—Dec., 1880. From the U. S. Patent Office.

Manual of Engineering and Mathematical Instruments made by Young & Sons. From Young & Sons.

Annual Reports of the Massachusetts Board of Education. 1850—1878–79 inclusive. From the Board, Boston.

Reports of the Second Geological Survey of Pennsylvania. G^4; H^5; I^3; P. R. From the Board.

Total Solar Eclipses of July 29. 1878. Appendix III to Observations for 1876. From the U. S. Naval Observatory.

Report of the Superintendent of U. S. Coast Survey for 1877. From the Coast Survey Office, Washington.

Annual Report of the Secretary of the Treasury on the State of Finances for 1880. From the Treasury Dept., Washington.

Annual Report of the Commissioner of Education for 1878. From the Bureau.

Annual Report of the Chief of Ordnance for 1880. From the Chief of Ordnance.

Manchester Steam User's Association Chief Engineers' Annual Refort for 1879. From the Association.

Steel Compressing Arrangements at the Barrow Works. By A. Davis. From the Author, London.

Report of the Department of Public Works, City of New York, for 1880. From the Department.

Report of the Commissioner of Internal Revenue for 1880. From the Commissioner.

Transactions of the American Philosophical Society. Vol. 15 N. S. Part 3. From the Society.

The Virginias, a Mining, Industrial and Scientific Journal. Edited by Jed. Hotchkiss. Vol. 1, 1880. From W. C. Macdowell, Philadelphia.

Memorial of Joseph Henry. Washington. 1880. From Hon. Chas. O'Neill, M. C.

Annual Report of the Adjutant-General of Pennsylvania for 1880. From the Adjutant-General.

Smull's Legislative Hand-Book for 1881. From G. W. Hall.

The Millstone. Vols. 2, 3 and 4. From the Publishers.

Houston's Intermediate Lessons in Natural Philosophy. Philadelphia: Eldredge Bros. 1881. From the Author.

Four Lectures on Static Electric Induction. By J. E. H. Gordon. New York. 1881. From D. Van Nostrand, Publisher.

Mr. J. Snowden Bell read an interesting paper on the Wootten Locomotive Engine, illustrating his remarks with drawings and diagrams. The paper is printed in full on page 340 of the JOURNAL.

Dr. Grimshaw inquired whether any experiments had been made with large drivers such as are used on English and French railways for fast service. He believed that the drivers on the Wootten engines were only about five and a-half feet in diameter, but on English railways they were made from nine feet to three metres in diameter.

Mr. Bell in reply said that the largest drivers he had ever heard of as being used in this country were eight feet in diameter. They were used on engines built thirty years ago. The largest now in use, he believed to be those on the new engine of the Pennsylvania road and they are only six feet six inches. It is certainly desirable to have large drivers, but in practical construction builders are limited by the requirements for the fire box.

Mr. Nystrom said that the diagrams showed the boiler elevated high above the track, this being made necessary by putting it over the driving wheels. He thought it would be better to turn the boiler end for end, bringing it down over the smaller or truck wheels.

Mr. Bell said that the great elevation of the boiler of the Wootten locomotive was invariably the first subject of criticism, but in practical work it did not prove objectionable. The Italian engineers found upon trial that the centre of gravity was not inordinately high. When he (Mr. Bell) worked in a locomotive engine workshop some years ago, it used to be the rule to put the boilers as low as possible. Now, the greater elevation is not objected to and some engineers hold it to be, in fact, an advantage.

Mr. Shaw said that he also had an impression upon looking at the Wootten locomotive that it was too high. He did not like the idea of riding on it, but he soon acquired confidence in the engine after trial. He commented on Mr. Nystrom's suggestion about turning the boiler around under the misapprehension that that gentleman proposed to turn the engine itself around, making the drivers run first.

Mr. Nystrom explained that he simply meant to move the boiler end for end, and in answer to a running fire of questions said he thought the centre of gravity would come all right, that the weight would be on the drivers, and finally, when asked what he would do with the cylinders, said he would arrange for them when he came to make the plan.

The Secretary's report included Ericsson's new caloric pumping engine which was exhibited by the H. B. Smith Machine Company. It is a very simple caloric engine, adapted for use in private residences, hotels, etc., and to be operated by unskilled labor. The air is alternately expanded and contracted in the chamber without allowing any of it to escape. This is accomplished by the use of a large displacing piston fitting loosely into the cylinder, and used to drive the air from end to end, without allowing any of it to escape, thus doing away with all valves. The air is first brought into contact with the lower part of the cylinder, where it is heated and expanded by a gas or coal furnace, and then carried to the upper part, where it is cooled by the water that is being pumped, and which passes directly from the pump into an annular space or jacket around the upper end of the cylinder, and thence to the discharge pipe. An air-tight piston closes the upper end of the air cylinder, and, when lifted by the expanding air beneath

moves the walking beam, and lifts the pump rod. The heated air upon being driven to the cold end of the cylinder is instantly cooled and contracted, and the momentum of the fly-wheel carrying the air-tight piston down, lifts the displacer, and thus drives the air to the hot end, when the operation is repeated. The air may be expanded and contracted three hundred times per minute. Either coal or gas can be used for heating, the latter being preferable, as the consumption is only fifteen cubic feet per hour. The engines are made of various sizes, from the six inch, capable of lifting 200 gallons of water fifty feet per hour, to the duplex 12-inch, capable of lifting 1600 gallons fifty feet per hour. The machine is entirely safe from dangers of explosion, and is very simple in its operation, and not likely to get out of order. The engine was used to pump water from a tub through a curved pipe and back again to the tub.

Mr. Holman called attention to the fact that the pipe was acting as a siphon and that the water was not being pumped the full height of the pipe.

The exhibitor said that was no doubt true, but the pump was capable of lifting 200 gallons per hour to a height of fifty feet. Having said that the engine was best adapted for pumping purposes because the water was needed to cool the cylinder, but that the engine might be used as a motor if the city water was used for cooling the cylinder, he was asked by Dr. Grimshaw whether water under the same head as that thus used if employed to drive a turbine would not yield as good results as the engine. He replied that that might be so; he had not examined the question. It was not, however, intended that these engines should be used as motors but only for pumping purposes.

Breitinger & Kunz exhibited Wenzell's system of air clocks, which has been in successful use in California for five years. The main clock or regulator must, of course, be a good time keeper. It is connected with a simple air pump worked by wheel work, and from the pump or pumps a small gas pipe is led away to the dial works, forty or more in number. These works are extremely simple, their only function being to provide for the movement of the hands in response to the pulsations of the air pumped by the regulator. The dials may be made of almost any desired form and cased entirely dust proof.

Dr. Grimshaw inquired as to the relative cost of the leaden

pipes used with these clocks and the copper wire used for electrical clocks.

Mr. Breitinger, the exhibitor, answered that that was a subject he had not considered and that he did not think it necessary to consider it, as the pipes need not be of lead. Gas pipes would serve the purpose. India rubber tubes were only used at the Institute for convenience.

Prof. Marks said that Prof. Rogers had experimented with a similar clock, and he understood had finally abandoned it because it was subject to so many accidents from variations in the state of the atmosphere.

Mr. Breitinger called attention to the fact that this apparatus was not open to such objections as the air was set free at each movement, the plunger or pump piston being lifted clear of the solution after each stroke.

Mr. Shaw also said that he did not think Prof. Marks would find this similar to the pneumatic pumps with which he had experimented. The pumps here used are miniature gasometers operating at a distance another gasometer. He inquired how far they would work, and Mr. Breitinger replied, from 1000 to 1200 feet with certainty. The liquid into which the piston is plunged is glycerin.

Mr. Shaw said he thought it a very worthy apparatus.

In answer to Mr. Spellier, Mr. Breitinger said that the heavy weights were required to drive the pumps. They are needed to run four dials, but would run forty just as well.

The United States automatic gas machine is an ingenious combination of devices for the generation of gas from the lighter oils and combining it with air for lighting and heating purposes. It is entirely automatic and, having been put in operation, makes the gas just as it is needed for consumption, no supply being kept on hand. The gasoline according to the plan is to be put in the yard in a cask connected by a small lead pipe with a pump in the cellar on the same level. There are also two cylinders, one to be heated by the gas of the machine, into which the oil is pumped in small quantities, and in which the gas is generated; the other an air cylinder from which air to be mixed with the gas is pumped by the movement of a piston actuated by the expansion of the gas in the process of its formation. Mechanical devices are employed to regulate the time of pumping, and thus to regulate automatically the supply of gas for